MIDDLE EAST AND
NORTH AFRICA

Background Paper
Water Scarcity and Droughts

World Bank Group

COUNTRY CLIMATE AND DEVELOPMENT REPORT

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Aknowledgements

This Background note was elaborated as an input to the preparation of the « Climate and Development » report (CCDR), under the leadership of Carole Megevand and Javier Diaz Cassou. It benefitted from contributions of many colleagues, in particular: Amal Talbi, Andrea Mariel Juarez Lucas, Carolina Dominguez Torres, Emma Renu Dalhuijsen, Ghita Hannane, Jacqueline Marie Tront, Julie Aurelie Carles, Malika Azzazene, Meryem Benjelloun, Michael Haney, Nabila Gourroum, Nancy Lozano Gracia, Rajesh K. Advani, Remi Trier, Safaa Bahije, Viviane Wei Chen Clement. The modeling exercises were carried out by Charl Jooste and Francis Dennig. This background note also hugely benefitted from the exchanges with the counterparts from the government, the private sector, academia and civil society.

Executive Summary

Morocco is one of the most water-scarce countries in the world. With a water endowment of nearly 620 m^3 per person and per year, it is already in a situation of structural water stress. Under demographic pressure, growing demand from economic sectors, combined with the impact of climate change, this could drop below 500 m^3 per person and per year by 2030 corresponding to a situation of severe scarcity. In addition, Morocco has been facing droughts, with increasing incidence, severity and duration, exacerbating the vulnerability in rural areas, with negative spill overs on macro-economic stability and food security at the national level.

Water scarcity could impact almost every aspect of Morocco's future socioeconomic development. With a longer-term perspective, the reduction in water availability and the drop in crop yields due to climate change could reduce GDP by up to 6.5 percent. Rainfed agriculture *(bour)* is particularly vulnerable to both droughts and water scarcity. Since rainfed agriculture still represents 80 percent of the country's cultivated area and employs most of the agricultural workforce, climate-induced changes (water availability and crop yield) on rainfed agriculture could result in out-migration to urban areas of up to 1.9 million Moroccans (about 5.4 percent of the total population) by 2050.

Large investments have been the cornerstone to address water scarcity. Over the past decades, Morocco has heavily relied on infrastructure to address the challenge of water scarcity and drought. It has invested in large dams and multiplied ten folds the water mobilization capacity (from 2 billion m^3 in the sixties to almost 20 billion m^3 in 2020). It also expanded the drip irrigation to increase water productivity in the agriculture, by far the most important water-consuming sector in Morocco. Moving ahead, Morocco has put forward an ambitious 2020-2050 Water National Plan (or PNE for a total CAPEX of US$41.3 billion over the next 30 years). The PNE aims at closing the water supply-demand gap by 2050, by increasing water mobilization (by 4.6 billion m^3/year) and enhancing water management efficiency both in potable water and agriculture sectors (that would generate a saving of about 2.2 billion m^3/year). To do so, it mostly relies on engineering solutions.

Investment in infrastructure is a necessary but not sufficient condition to tackle the challenge of water scarcity and reforms on water demand policies need to be pursued. The analysis carried out as part of the Morocco CCDR and presented in this background paper, shows that given the high level of vulnerability of Morocco to both droughts and water scarcity, investing in water infrastructure yields positive returns for the economy and should remain a priority. However, based on international experience and an extensive body of academic research, the CCDR also argues that these returns will not fully materialize unless infrastructure development is paired with additional "soft" measures, such as water demand management, water governance, and other actions designed to bring about behavioral changes. This is aligned with the NDM, which recommends *"reflecting the true value of the water resource and incentivizing a more efficient and rationale use and management of the resource."*

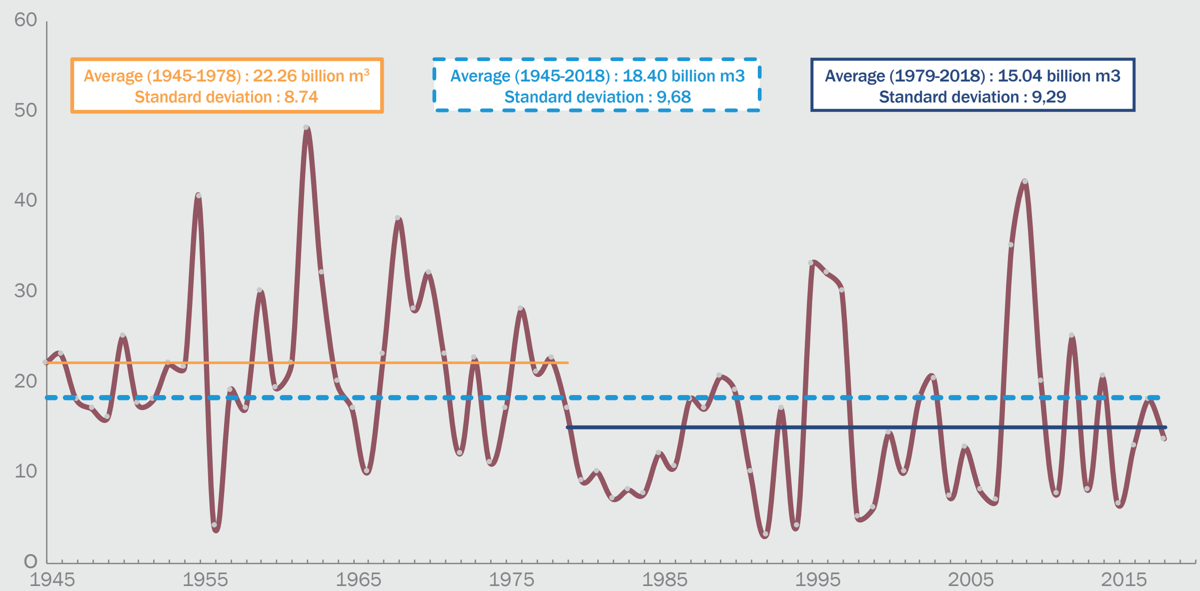
Historic trends: Water Scarcity and Droughts in Morocco

1.1. A Declining and Deteriorating Water Resource

Morocco is amongst the most water-stressed countries in the world. Water resources in Morocco are estimated at 22 billion m^3, divided into 18 billion m^3 of surface water and 4 billion m^3 of groundwater. With an average temperature increase above global warming trends and an overall decrease in precipitations (with more erratic patterns), Morocco has witnessed, over the past decades, an accelerated trend towards the depletion of water resources. The per capita availability (potential) of renewable water resources in Morocco decreased from 2,560 m^3 per person and per year in 1960 to about 620 m^3 per person and per year in 2020[1] , which places Morocco in a situation of structural water stress[2], as most of the MENA countries. Morocco could reach the absolute water scarcity threshold of 500 m^3 per person per year before the end of this decade.

Morocco has become drier over the past decades with a downward trend in surface water availability. About 70 percent of Morocco's water is concentrated in 15 percent of the national territory (covering the northern river basins). Surface water variability is high, varying from 3 billion m^3 to 48 billion m^3.[3] Based on the time series used by the National Plan for Water (or PNE)[4] on rainfall precipitation (1945-2018), the annual average inflow is 18 billion m^3/year. But the World Bank analysis shows that, since 1979, Morocco has seen its water inflows (surface water) declining: from an annual average of 22 billion m^3 between 1945 and 1978 (blue line) to an annual average of 15 billion m^3 between 1979 and 2018 (red line). In addition, while there was an 80 percent probability of having an annual inflow of 15 billion m^3 between 1945 and 1978, this probability declined to a mere 50 percent between 1979 and 2018 (see Figure 1).

Figure 1: Morocco's water inflows (in billion m^3/year)



Source: World Bank team's calculation based on PNE 2020

1 PNE, 2021
2 Countries are said to experience water scarcity if they have less than 1,000 m^3 of renewable water per person per year. Under 500 m^3 of renewable water per person per year, countries are in a situation of absolute water scarcity.
3 Draft PNE.
4 According to the Water Law 36-15 the PNE encompasses the actions to be taken by the various stakeholders for the next thirty years to ensure the country's water security. The draft PNE was presented to the Interministerial Water Commission on December 2019 and is pending submission for approval by the High Council for Water and Climate.

Pressure on groundwater resources has increased. Morocco started to use groundwater recourse in response to the drought of the late seventies. Groundwater now accounts for about 35 percent of all water used in agriculture, but in drought years its share can significantly increase. Overall, groundwater withdrawals amount to about 5 billion m^3 per year, which exceeds by 28 percent (or 1.1 billion m^3 per year) the estimated level of renewable groundwater sources[5]. The lack of data on nonrenewable groundwater (its quality and quantity)[6] makes it difficult to assess how long Morocco can rely on groundwater overuse to cover its increasing water demand.

Despite scarce water resources, both potable and irrigation water systems are plagued with substantial losses in the transport and distribution networks. It is estimated that the physical water loss in the distribution networks is estimated at around 24 percent (ranging from 17 percent in the city of Salé to 38 percent in the city of Essaouira). In addition to these losses, there are also the losses of transport of treated water (5 to 10 percent), treatment (5 percent) and in some cases losses in transport of raw water (10 to 20 percent).

The challenge of water scarcity is compounded with the deterioration of water quality. While the overall surface water and groundwater quality in Morocco is acceptable or good, one can observe a downward trend. Only 54 percent of the population[7] is connected to wastewater treatment plants and less than half of the wastewater collected is treated[8] before being released into oceans, rivers, and soil. Most industrial sewage is disposed untreated directly into the environment. The agriculture sector contributes to significant amounts of pollution to water sources through uncontrolled use of pesticides and fertilizers[9] .

The interdependencies between the water and energy systems are clear and becoming more prominent. Water is used in all phases of energy production and electricity generation, while energy is also required to extract, convey and deliver water and to treat wastewaters prior to their return to the environment. Managing the water-energy nexus is at the heart of the development challenge in Morocco (see Box 1 on Water-Energy Nexus).

Box 1: Water-Energy Nexus

In the 1970s, the mobilization of water by dams resulted in an increase in hydropower generation, which represented more than 70 percent of the installed power generation capacity of the country. Dams were most often multipurpose, also delivering water management for distribution and irrigation. As of today, the contribution of hydroelectricity has fallen to 17 percent of total installed generation capacity.[10]

The PNE (National Water Plan) envisions recourse to nonconventional water resources, notably the desalination of seawater,[11] which is based on energy-intensive technologies.[12] In order to be compatible with Morocco's decarbonization targets, these plants will have to receive their energy from renewable energy sources, essentially wind and solar power. There is significant potential for energy savings in the water sector if all of the economically available options for energy efficiency and energy recovery are exploited. Wastewater reuse is energy-demanding, but it also contains significant amounts of embedded energy that, if harnessed, could cover more than half of the electricity needs of municipal wastewater utilities.

On the energy front, Morocco has the ambition to become a large producer of green hydrogen (GH) and its derivatives[13], such as ammonia, which are an important input to Morocco's large phosphate-to-fertilizer industry. But GH requires clean water and renewable energy. It is worth noting that desalinated water would, however, only represent a small part of the cost of GH production; and that it may be possible to produce GH using treated wastewater in the future.

On both the energy and water fronts, there are significant margins for the improvement of efficiency and loss reduction along the supply chains. Priority should be given to efforts to save water and energy: boosting energy efficiency throughout the water sector value chain, and minimizing water use in the power sector–for example replacing water cooling with air cooling whenever possible–are also important ways of making both sectors more efficient.

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[5] As groundwater is a local resource stored in many aquifers with a limited geographical extent, this percentage of over-use at a national level hides the intensity of over-use in some critical aquifers. The groundwater overuse varies from 100 percent in the Moulouya to 248 percent in Chtouka-Massa (source: Geosciences 2020, 10, 81, Moroccan Groundwater Resources and Evolution with Global Climate Changes)

[6] The PNE and the PDAIREs do not report information on the quantity and quality of the groundwater in Morocco.

[7] This represents about 20 million Moroccans in urban and peri-urban centers.

[8] Wastewater treatment capacity grew from 50,000 m^3/day in 2000 to 900,000 m^3/day in 2016 (not including submarine outfall). Today only 21 percent of the collected effluent is treated, with 30 percent pretreated before discharging it through submarine outfalls to the sea.

[9] Estimated at 1,200 tons of nitrogen and 500 tons of pesticides per year

[10] L The decrease in the share of hydroelectricity is not only the result of the reduction in water supply, but also of the development of thermal power stations since the 1980s, and the constraint of managing dams to meet irrigation demand.

[11] The 2050 National Plan for Water (PNE) includes seawater desalination projects that are projected to produce nearly 1 billion cubic meters/year in order to secure drinking water in large cities and, to a lesser extent, to consolidate the water supply in some irrigation perimeters.

[12] The share of energy consumption represents up to 60 percent of the operating cost of desalination plants.

[13] The ministry in charge of energy issued a Green Hydrogen Roadmap in 2021,

1.2. Socio-economic impacts of droughts

Agriculture performance remains highly correlated to rainfall patterns. Agriculture remains a key sector for Morocco's economy, accounting for approximately 13 percent of Morocco's GDP, 23 percent of its exports, and nearly to 30 percent of its total employment. While Morocco has massively invested in water management infrastructure (dams, modernization of irrigation) over the past decades, the overall agriculture sector performance remains highly vulnerable to climate shocks, with rainfed areas still representing close to four fifths of total cultivated areas and contributing to more than 40 percent of agricultural value added in average years. As a result, agriculture performance experiences large swings depending on the level of precipitations[14]. Cereals, and in particular wheat, constitute the most important rainfed crop both in terms of value and of relevance for food security. Evidencing the comparatively large variability of wheat production in Morocco, the coefficient of yield variation for that crop reached 0.34 between 2000 and 2020, against 0.23 in Tunisia, 0.18 in Algeria and Spain, 0.11 in France and 0.06 in Turkey (calculations based on FAOSTAT data)[15].

Changes in precipitation levels are a major source of macroeconomic volatility in Morocco. The Figure 2, Figure 3 and Figure 4 illustrate the high correlation between changes in rainfall, cereal production and agricultural value added. Through backward and forward transmission channels, adverse impacts on the agriculture sector have knock-on effects on other sectors of the economy, An econometric analysis confirms that erratic rainfall still constitutes an important and persistent source of macroeconomic volatility in Morocco. On average, rainfall shocks explain close to 37 percent of the variance of Morocco´s output over the medium-term, as estimated with a Forecast Error Variance Decomposition (FEVD) of the structural vector autoregressive (SVAR) model described in Box 2 and Figure 5.

Figure 2: Cereal production and rainfall

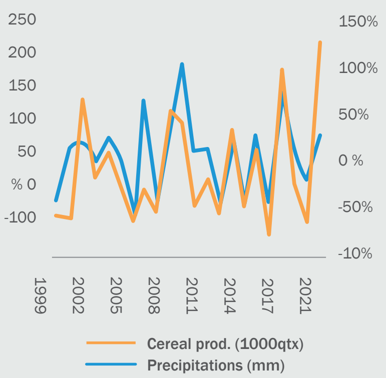


Figure 3: Agriculture Value Added and rainfall

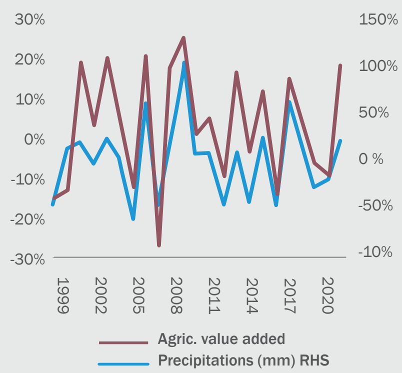
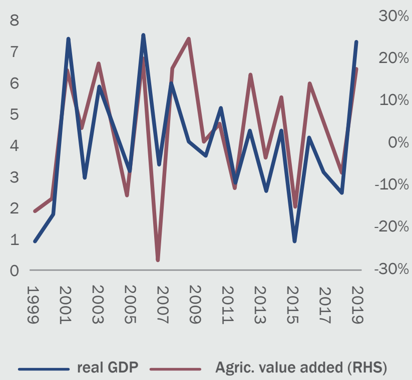


Figure 4: Agriculture Value Added and GDP



Source: Authors' calculations

[14] Such fluctuations are mostly linked to the level and temporal distribution of precipitations across the agricultural season.
[15] The coefficient of yield variation is defined as the standard deviation of a given crop expressed in volumes divided over its mean.

Box 2: A SVAR analysis on the impact of rainfall shocks in Morocco

An econometric analysis confirms that erratic rainfall still constitutes an important and persistent source of macroeconomic volatility in Morocco. A structural vector autoregressive model (SVAR) was used to study the effect of rainfall shocks on the gross domestic product of Morocco. The model was estimated with annually growth of average quarterly of precipitation (R_t) and GDP_t for the period 2001q1-2019q4. Formally, the SVAR can be represented as follows:

$$A_0 Y_t = A_+ X_t + \varepsilon_t \quad (1)$$

Where $Y_t=[R_t \ \ GDP_t]$ is the vector of the n endogenous variables, $X_t= [Y_{(t-1)} \ ...Y_{(t-p)} \ \ 1]$ is the vector of k (nxp) explanation (lagged) variables, ε_t is the vector of n structural shocks with Normal distribution $N(0,I_n)$. A_0 et $A_+=[A_1...A_p \ \ C]$ are the matrix of structural parameters for j=0,...,p, n s the number of endogenous variables, p is the number of lags (selected with Akaike Information Criterion), T is the sample size.

Since the stationary condition of the endogenous variables and the matrix A_0 is invertible, a moving average representation was used to explain GDP (demeaned) as a function of structural shocks (historical decomposition):

$$GDP_t = \sum_{s=0}^{t-1} \theta_R^{GDP}(s) \times \varepsilon_{R,t} + \theta_{GDP}^{GDP}(s) \times \varepsilon_{GDP,t} \quad (2)$$

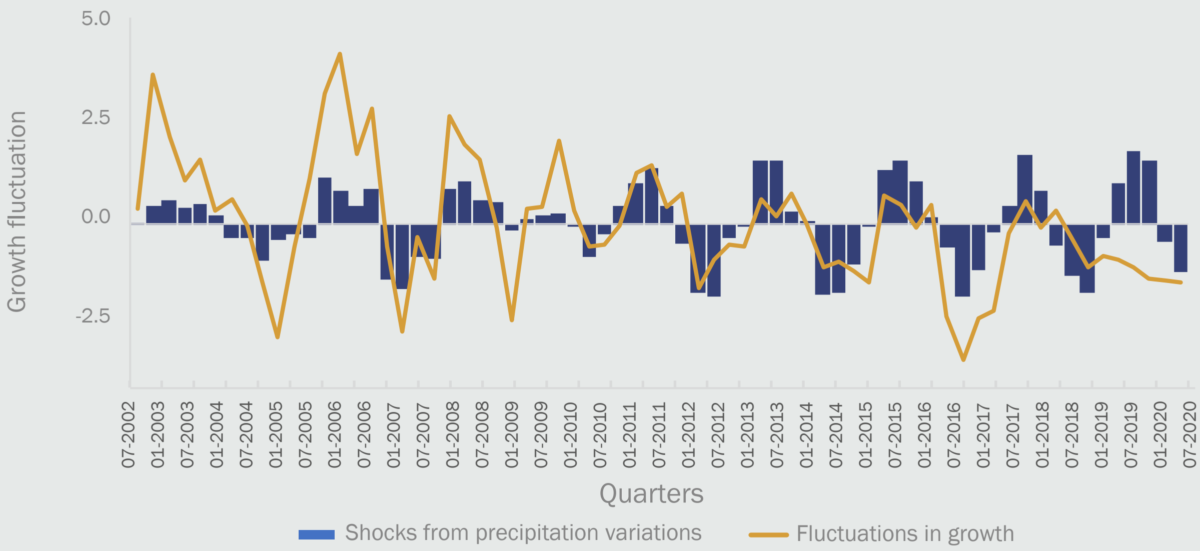
With equation (2) we can (historically) decompose the fluctuations of the annually growth of the GDP between the shocks of precipitation $\varepsilon_{(R,t)}$ and output $\varepsilon_{(GDP,t)}$,, where $\theta_j^i(s)$ represents the response of ith endogenous variable to jth structural shock at time s (impulse-response function).

The forecast error variance decomposition (FEVD) was used to capture the participation of precipitation shocks on the fluctuations of the GDP. For this purpose, we estimated the squared cumulative effect of rainfall on GDP (squared impulse response function) up to horizon h. In addition, we obtained the forecast error covariance matrix (minimum squared prediction error) at horizon h, that it is the sum up of the contribution of the precipitation and output shocks. Formally, the FEVD can expressed as:

$$FEVD_{GDP,R,h} = \frac{\sum_{s=0}^{h-1}(\theta_R^{GDP}(s))^2}{[\sum_{s=0}^{h-1}(\theta_R^{GDP}(s))^2] + [\sum_{s=0}^{h-1}(\theta_{GDP}^{GDP}(s))^2]} \quad (3)$$

On average over the medium-term, rainfall shocks explain close to 37 percent of the variance of Morocco's GDP forecast error, which is substantially higher than the weight of agricultural value added over GDP (around 13 percent on average over the past decade). (Figure 18) illustrates the weight of rainfall shocks as a driver of quarterly demeaned GDP growth fluctuations over recent decades.

Figure 5: Historical decomposition of the annual variation of GDP (SVAR)



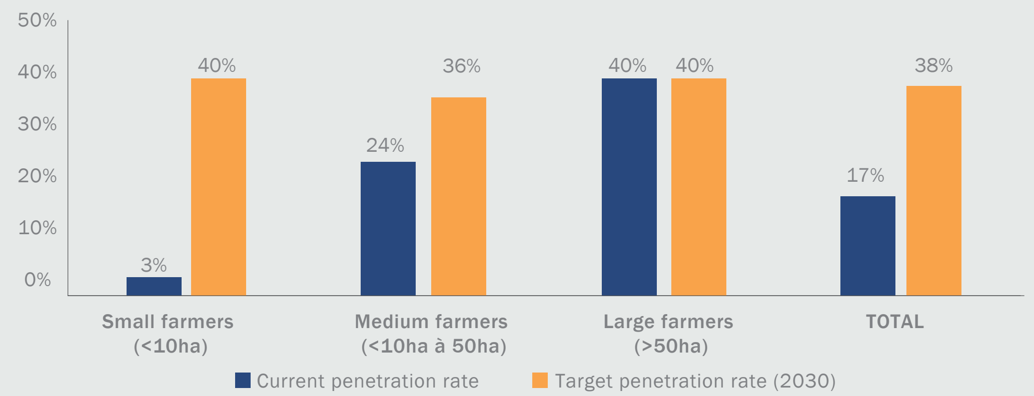
Note: the line is the demeaned rate of annual growth of GDP, the blue bar represents the contribution of precipitation shocks.
Source: Authors' calculations

Droughts exacerbate the vulnerability in rural areas, with significant social consequences. With about 79 percent of the poor in rural areas, poverty in Morocco remains largely rural. Rural livelihood is intrinsically linked to agriculture[16], with a large majority of rural population relying on agriculture for income and food. The increasing incidence, severity and duration of droughts in Morocco have become a key driver of vulnerability in rural areas[17], with risks of income losses, asset depletions, malnutrition and eventual migration. While Morocco has made progress on agriculture insurance penetration rate, it is still low with only 17 percent of agricultural areas insured against climate risks and a limited access for the small farmers (below 3 percent). Increasing the agriculture penetration rate, particularly for the small farmers, who happen to be the most vulnerable to shocks (as the less equipped to promptly recover from shocks is a core priority under the new Green Generation Strategy (see Figure 6).

Drought episodes create a reliance on cereal imports, threatening the national food security. Morocco is a net importer of cereal products such as wheat and barley. During drier years, the grain imports surge to compensate the shortage from domestic production affected by droughts. For example, when Morocco's wheat production plummeted to 2.7 million tons in 2016, from 8.1 million tons in 2015, the country's wheat imports doubled to 6.3 million tons in 2016, from 3.2 million tons in 2015 (see Figure 7)[18]. Barley production and imports in Morocco also shows a similar pattern at a smaller extent, compared to the wheat production and imports (See Figure 8). Even irrigated agriculture products can be affected by weather conditions as this is the case for citrus. Although citrus exports have been strongly correlated with the expansion of irrigation, they can still be affected by extreme weather events. High temperatures affect 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.

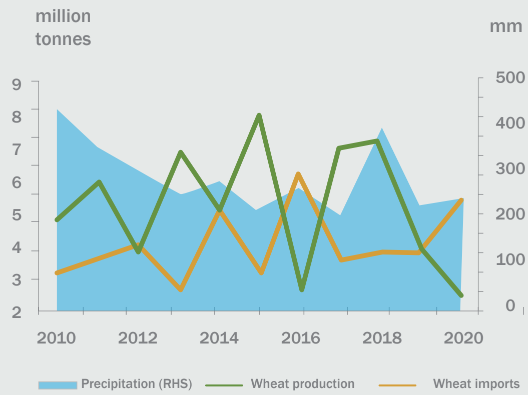
[16] More than 80 percent of rural population working in the agriculture sector, with about 70 percent of Morocco's farms smaller than 5 hectares.
[17] Women and youth are particularly exposed. About 73 percent of female labor in the primary sector is unpaid, a share that is even higher than the 60 percent unpaid labor rate for youth.
[18] An in-depth study assessing the relationship between cereal production and droughts in Morocco found that the vegetation conditions and land area conditions during March April are highly correlated to yield while a temperature condition is linked to crop development stage in January and February.

Figure 6: Climate Multi-Risk Insurance penetration rate for large crops (current and target 2030)



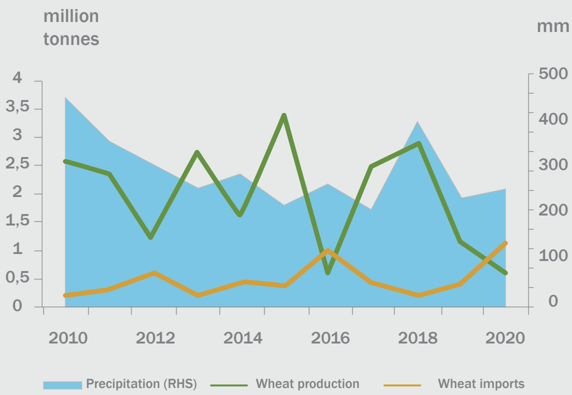
Source: Ministry of Agriculture, 2020

Figure 7: Morocco's wheat production, imports, and precipitation



Source: FAOSTAT.

Figure 8: Morocco's barley production, imports, and precipitation



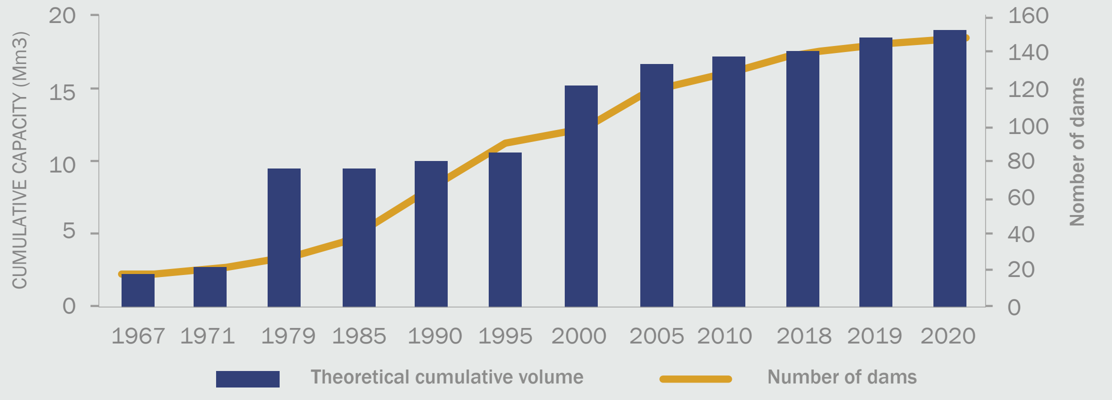
1.3. Past efforts to tackle water scarcity: ambitious plans with some shortcomings

Morocco has developed massive infrastructure (dams and water interconnections) to increase its capacity to mobilize water. In 1967, His Majesty the King Hassan II launched an ambitious program to construct dams. Since then and up to 2020, the number of large dams increased from 20 to 146, and the total design storage capacity increased from 2 to 19.1 billion m^3 (see Figure 9). Also, Morocco developed 15 water basin interconnections (about 785 km) to secure municipal water supply and irrigation, mainly Casablanca, Doukkala, Haouz, Marrakech, and Nador.

But over time, large dams have become less efficient at mobilizing water resources. The variability and decline in rainfalls have put the actual water volume in reservoirs on a downward trend over the past decade (see Figure 10). This is compounded with the loss in volumes due to the siltation phenomenon caused by the erosion from the upstream watershed estimated at about 100 million tons per year (with about 60 percent deposited in reservoirs)[19]. Other important facts related to siltation of dams: (i) nearly 20 reservoirs or large dams will be completely silted up by 2040; (ii) almost half of the dam reservoirs would lose near 50 percent of their capacity in 2050 and (iii) almost all of the small dams built would probably be silted up by 2040. By end of February 2022, in the midst of yet another severe drought, the overall filling rate of the main dams has hit a historical low of 32.8 percent of the total capacity (with some of the dams below 10 percent).

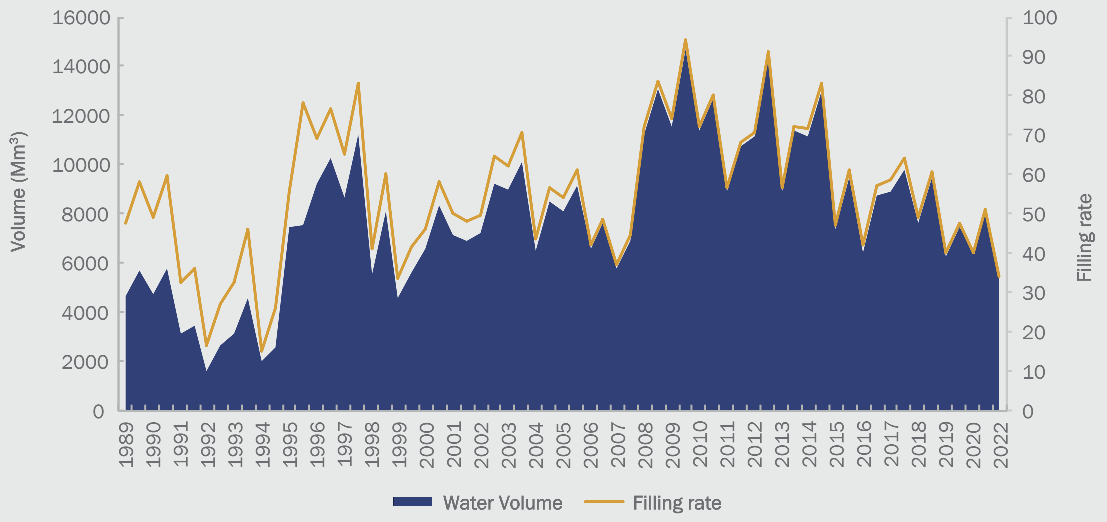
[19] JICA study on Dam Sedimentation in Morocco, presented in a workshop in November 2021.

Figure 9: Evolution of dam capacity and number of dams* in Morocco over the past 50 years



Source: PNE
Nota *Large dams only

Figure 10: Registered water volume of main dams* in Morocco in past 30 years



Source: Ministry of Equipment and Water (2022)
Nota: *depicted volumes and filling rates correspond to varying total number of dams per year, ranging from 20 up to 62 total dams

In addition, Morocco has made significant advances to increase water productivity in the agriculture sector, by far the most water consuming sector in the country. This was done with the modernization of the irrigation system including on-farm equipment (through the Program for Water Savings in Agriculture or PNEEI under the Plan Maroc Vert or PMV) supported by a high rate of subsidies under the Agricultural Development Fund (or FDA). After 12 years of implementation, multiple positive outcomes came out of the PNEEI[20]: The areas under drip irrigation have increased 3.5 times through PMV with additional 560,000 hectares (about 37 percent of total irrigated area)[21],

[20] World Bank. 2020. "Morocco: Green Generation Program-for-Results." Project Appraisal Document, World Bank, Washington, DC.
[21] Bilan Plan Maroc Vert (2008-2018) -MAPMDREF

reaching a total area of irrigated land of around 1.7 million hectares in 2021[22]. With a cumulative investment under the PMV of US$10 billion over 2008-2018 (40 percent public, and the remainder leveraged from the private sector, including farmers), the PMV has achieved remarkable results, including (i) the doubling of water productivity (from 0.25-0.5 USD/m^3 to 0.5-1.0 USD/m^3); (ii) an almost doubling of the agricultural value added in real terms (from approximately US$65 billion to US$125 billion through a shift towards higher value-added crops (see Figure 11); (iii) a decline in the volatility of agricultural sector growth (see Figure 12) and (iv) overall, a notable increase of farmers' income (between 40 and 100 percent)[23]. While representing only 20 percent of the agricultural lands, irrigated areas contribute to more than half of the total agricultural value added[24]. The value added of agriculture areas is about four times the value added of rainfed area for a year with average rainfall and could go beyond 70 percent in a dry year[25]. See Table 1.

Figure 11: Trend in Ag value added and rainfall over the 1998-2018 period

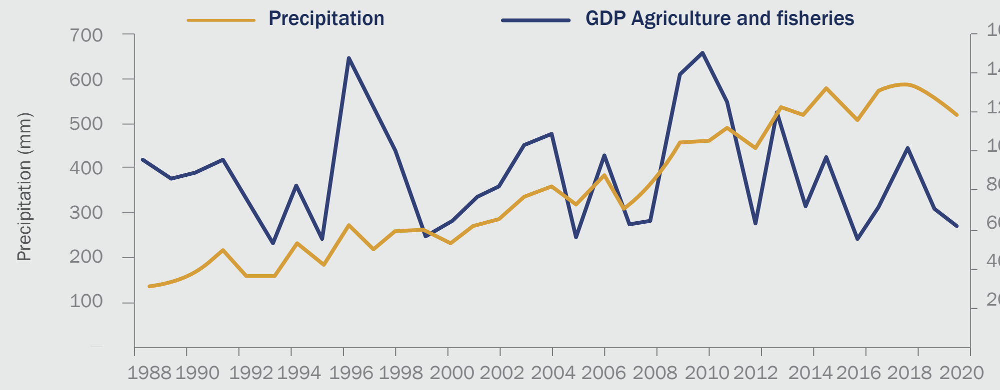
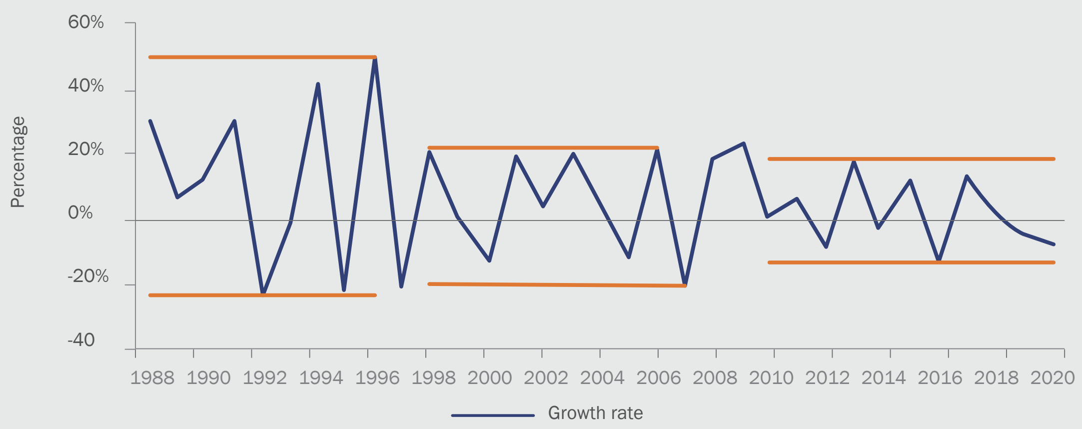


Figure 12: Evolution in Ag growth variability over the 1998-2018 period



Source: Ministry of Finance and HCP data (2019), World Bank Ag Sector Review (2020). Ministry of Agriculture (2021)

[22] The uptake of modern on-farm technology (mainly drip systems) has been a success for individual farmers, equipping 395,000 hectares (117 percent of the target); the uptake has been slower for the 70,000 small farmers targeted in collective schemes.
[23] According ICR of WBG and ADB projects as well as results from M&E system of PMGI project.
[24] Irrigated agricultural value added can surpass 70 percent of total agricultural value added in a dry year. Source: Social Accounting Matrix, 2020.
[25] Source: World Bank staff calculations building from Social Accounting Matrix, 2020.

Table 1: Share of cultivated areas and added value by irrigated and rainfed areas

	Irrigated		Rainfed		Total	
Cultivated areas	ha	%	ha	%	ha	%
	1 728 330	20 %	7 034 464	80 %	8 762 794	100,0
Value Added	Million MAD	%	Million MAD	%	Million MAD	%
	45 632	53 %	40 421	47 %	86 054	100

Source: World Bank staff calculations building from Social Accounting Matrix, 2020.

Despite its positive outcomes, the PMV has failed to reduce the pressure on water resources. The conversion to modern on-farm irrigation equipment did not lead to a reduction in the consumption of irrigation water at farm level. This is explained by fact that, when not constrained in water use, farmers equipped with drip irrigation would tend to intensify production through a shift toward crops with higher added value, which consumes more water. This phenomenon, referred to as the "Jevon's paradox"[26], has put a significant pressure on the underground water resources that are now over-exploited, with withdrawals surpassing by 28 percent the level of renewable resources. In addition, the water tariffs have been maintained artificially low and fail to capture the increasing scarcity of the resource, which combined with unconstrained water supply can lead to over-consumption patterns (see Box 3).

Box 3: Water Tariffs in Irrigated Agriculture

Water pricing in irrigated agriculture is divided into: (i) water use or Domaine Public Hydraulique (DPH) fees[27]; and (ii) service provision (or irrigation) fees. These two types of fees serve different functions and purposes.

The DPH fee represents the price for water withdrawal. It aims to contribute to the operational costs of the water basin agencies (Agences de Bassin Hydraulique, or ABH) to help them carry out their functions (including water policing), as well as contributing to the operating and maintenance (O&M) costs of dams and other hydraulic assets under ABH. Currently it is set at a very low level (MAD 0.02/m^3). It is supposed to be paid by all water users; however, the actual collection level represents only a very small portion of the potential level. Between 2012 and 2017, the fee collection from irrigation users ranged between MAD 26 and MAD 40 million per year, while the potential amount would be about MAD 280 million per year[28]. The amount collected comes mostly from large-scale irrigation schemes (LSIs)[29]. The DPH fee is not collected for small-scale irrigation (SMI) schemes (which is roughly 19 percent of irrigated areas), or for private irrigation (PI), which represents more than 45 percent of irrigated areas and uses mainly underground water or run-off river resources. This situation leaves ABH with very limited resources that do not allow them to fulfill their mandate, most notably their role of water police.

The service provision fee (or irrigation fee) has a very different purpose and relates to irrigation services provided to users. Morocco has progressively put in place a service charge system, allowing a better coverage of irrigation

[26] The Jevons paradox refers to situations when technological progress or government policy increases the efficiency with which a resource is used (reducing the amount necessary for any one use), but the rate of consumption of that resource rises due to increasing demand and unconstrained supply.
[27] Fee linked to the use of water within the Domaine Public Hydraulique (DPH).
[28] Considering the total average water volume allocated to irrigation by year (14 billion of m^3) with a fee of MAD 0.02/m^3.
[29] With the ORMVAs (Regional Offices for the Agricultural Valorization) collecting on behalf of the ABH.

water service costs compared to other major irrigation countries. The purpose of this fee is to cover the O&M and amortization costs of collective irrigation systems. By definition it applies to both LSIs and SMIs, but not to PIs (which rely on individual schemes). In SMIs, where irrigation schemes are usually traditional, the irrigation fees represent low amounts paid by the farmers to the Water User Associations (WUAs). On the contrary, LSI has put into place water pricing systems that aim to reflect the quality and the costs of services according to the schemes: as such, the fee amounts vary widely (between 0.24 and 0.77 MAD/ m^3 in LSIs under Offices Régionaux de Mise en Valeur Agricole (ORMVA, i.e., regional offices for agricultural enhancement), ORMVA's management, and between 1.5 to 5.5 MAD/ m^3 under public/private partnership (PPP) schemes).[30] The collection rate is high for most LSI schemes (in the range of 80 to 95 percent)[31]. However, it is important to note that with these fees, the users' willingness to pay is correlated with the quality of the services delivered. Over the past few years, some collective schemes have been subjected to severe water rationing, therefore to unreliable It is also worth noting that the water tariffs do not reflect the high level of public investment in support of irrigation (CAPEX)—both for large water infrastructure, but also for modernization subsidies for irrigation equipment at the farm level (supported at 80 to 100 percent through FDA subsidies).

The increasing frequency and incidence of drought episodes have also conducted to water rationing measures in some irrigated perimeters. Morocco has set a guiding principle that the water demand for all sectors except agriculture would be systematically fulfilled (and that the water demand for irrigation would be accordingly adjusted based on the water availability). As a consequence, some collective schemes (e.g, in Oum Er Bia, Moulouya, Souss-Massa or Tensift) were submitted to severe water rationing over the past years[32], with immediate impacts on the farmers' revenues. This fuels a vicious circle where their willingness to pay for the service provision fee is reduced, which in turn further undermine the quality of the service.

[30] Morocco was one of the first countries in applying PPP schemes in irrigation (i.e. Guerdane, Choutka,...).
[31] This is based on a 2014 survey (which is the latest official data); it is very likely that the collection rate would be lower now given the restrictions applied in terms of water allocation in recent years.
[32] Some irrigation perimeters were allocated any water resource in 2022.

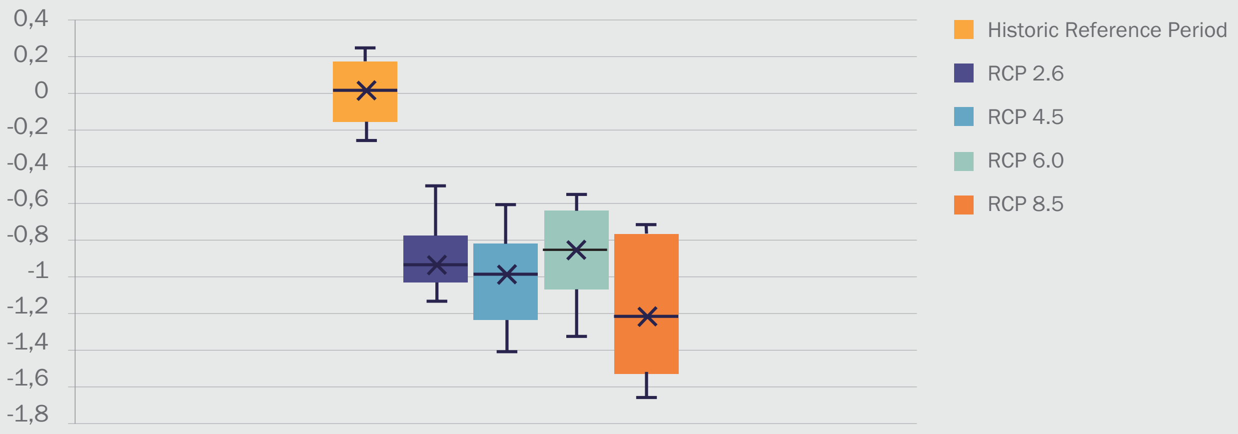
Water Scarcity & Droughts: A Major Threat on Long-Term Development

2.1. A Growing Tension between Water Demand and Supply

The demand for water is projected to grow from all sectors. The water demand is projected to increase from 16.2 billion m^3/year in 2020 to 18.6 billion m^3/year by 2050. Agriculture would remain the largest consumer of water resources with more than 16 billion m^3 by 2050 (an increase of 10 percent from 2020). Water demand from urban and rural households is expected to increase respectively by 50 percent (from 1.1 to 1.7 billion m^3/year) and by 20 percent (from 320 million m^3/year to 390 million m^3/year) during the same period. Other sectors would see a significant rise in demand, notably tourism with an increase of 5 folds (from 33 billion m^3/year in 2020 to 106 billion m^3/year in 2050) and the industry (excluding phosphate industry) with an increase by 2.4 folds (from 64 billion m^3/year in 2020 to 156 billion m^3/year[33]).

Water resources are projected to decline due to climate change. Precipitations are projected to decline with climate change, through increased arid periods and drought conditions. Additionally, projections indicate that winter precipitation will be reduced thus, the availability of water for irrigation from mountain streams and reservoirs will continue to be stressed at an increasing rate, with severe water shortages for the arid southern regions. Under all climate scenarios Morocco is thus projected to experience significant and extreme dry conditions as well as increased and prolonged pressure on water resources by mid-century and by end of the century is likely to be experience severe drought conditions and water scarcity (see Figure 13 on annual Standardized Precipitation Evapotranspiration Index (SPEI)[34]). The warming and drying trends are expected to exacerbate during the second half of the century.

Figure 13: Projected Water Deficit (Annual SPEI Historical*and 2050 projected trends



Source: World Bank Climate Change Knowledge Platform CCKP

[33] The consumption from phosphates industry is projected to remain almost unchanged from 115 billion m^3/year in 2020 to 128 billion m^3/year in 2050.

[34] The annual Standardized Precipitation Evapotranspiration Index (SPEI) is an index which represents the measure of the given water deficit in a specific location, accounting for contributions of temperature-dependent evapotranspiration and providing insight into increasing or decreasing pressure on water resources.

The tension between water demand and water supply is expected to further grow. At present, the water demand-supply gap amounts to as least 1.8 billion m³/year at the national level[35], with structural deficits registered in the Souss-Massa, Tensift, and Moulouya basins. This gap is expected to grow given the trends in water demand as presented in the previous paragraph (18.6 billion m³/year) and projects the change in mobilized water supply taking into account the dam siltation and the commissioning of dams currently under construction (14.6 billion m³/year) which would bring the water deficit to 4 billion m³/year by 2050. The water deficit would further widen if impacts of climate change are taken into account, i.e. an increase by 10 percent of the demand for the agriculture sector (bringing the total demand at 20 billion m³/year) and a decline in precipitation and underground water resources. Under such circumstances (bringing the total mobilized water at a low 13 billion m³/year), the water deficit could get as high as 7 billion m³/year. See Figure 14 and Figure 15.

Figure 14: Projected water mobilization and water demand measures planned under the PNE

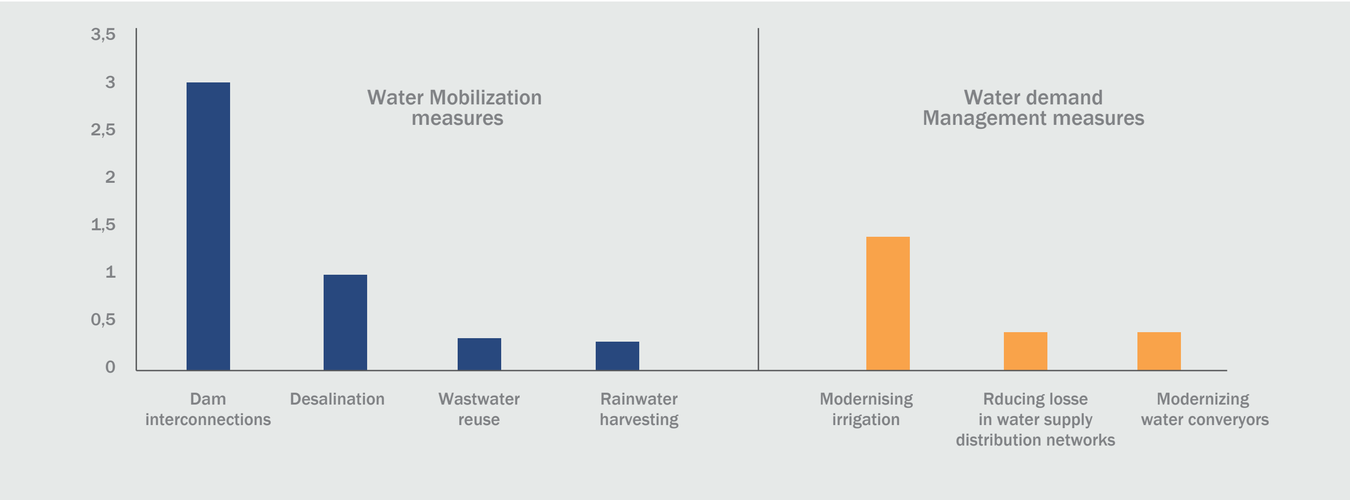


Figure 15: Projected water deficit over the period 2020-2050 period (with and without climate considerations)

Source: Authors' calculations (based on the PNE, 2021)

[35] PNE total water demand and water supply amount respectively to 16.249 billion m³/year and 14.473 billion m³/year in 2020.

2.2. Projected Impacts of Water Scarcity and Droughts

Water scarcity could potentially impact almost every aspect of Morocco's future socio-economic development. Morocco could reach the absolute water scarcity threshold of 500 m^3 per person per year before the end of this decade. However, the development in Morocco turns out to be thirsty with an increase in water consumption in all the sectors (potable water, agriculture, industry, tourism). The below section sheds light on the multi-faceted impacts of water scarcity and their cascading effects through the entire economy, looking at different dimensions such as growth, jobs, trade but also domestic migration.

A recent World Bank analysis on water scarcity in Morocco[36] has put in light the many ripple effects water scarcity and climate change could have on the Moroccan economy. In 2020, the World Bank completed an assessment to examine the impacts of water scarcity and climate change in Morocco using the computable general equilibrium (CGE) model from the Global Trade Analysis Project (GTAP), also known as GTAP-BIO-Water. A large set of scenarios was built in order to quantify future impacts of different parameters, notably the changes in water availability, the change in crop yields due to climate change, but also the impacts of investments in improved water use efficiency (WUE) (see Box 4).

Box 4: Modeling the impact of Water Scarcity on the Economy - GTAP-BIO-Water Model

GTAP-Bio-Water 's main features

The Global Trade Analysis Project (GTAP-BIO-Water) model is a computable general equilibrium (CGE) model that captures economy-wide impacts, including changes in prices, quantities and incomes engendered by fluctuations in goods and services using water as an input. The main feature of the model is that information on economic performance is disaggregated by isolating the role of water as a production input. Thus, the model incorporates water into the production function of all economic activities, including crops, livestock, industries, and utility services. Unlike other existing global CGE models, this model distinguishes between rainfed and irrigated.

The CGE model provides projections of impacts in changes in inputs (water available, climate conditions, allocations across sectors), and help improve the understanding of the direction and magnitude of changes and how alternative policies accentuate or mitigate adverse consequences. Since CGE models capture interlinkages across factor and product markets in an economy, they are useful in tracing effects that might cascade through the economy.

GTAP-BIO-W model was used to simulate the impacts of:

First set of simulations: Reductions in water supply from 10 to 25 percent with 5 percent increments (simulations S1 - S4)

Second set of simulations: Reduction in water supply (from 10 to 25 percent with 5 percent increments) plus yield changes induced by climate change (simulations SC1 – SC4)

Third set of simulations: Reduction in water supply (from 10 to 25 percent with 5 percent increments) plus yield changes induced by climate change; and a 20 percent improvement in productivity of water used in irrigated crop sectors[37] (SC1-W20 to SC4-W20)

Four set of simulations: Reduction in water scarcity (from 10 to 25 percent with 5 percent increments) plus yield changes induced by climate change and a 10 percent improvement in productivity of water used in irrigated crop sectors (and SC1-W10 to SC4-W10)

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36 See "Water Scarcity in Morocco" report

37 The assessment examined the extent to which improvements in water use efficiency (WUE) could mitigate the adverse impacts of water scarcity, using the target of 20 percent at set forth in the National Irrigation Water Saving Program (PNEEI).

Five set of simulations: Improvements in water use efficiency (WUE) from 5 to 20 percent by 5 percentincrements, to estimate rebound effect[38] (simulations R1 to R4 without climate considerations and RC1 to RC4 with climate considerations)

Simulation from 1 to 5 used limited substitution elasticities among primary inputs in crop sectors and assumed no water movement between irrigation and other activities.

Six set of simulations (flexible): allows water to move between irrigation and other uses and makes it possible to substitute water-land with other primary inputs. Simulation examines this case combined with a 25 percent reduction in water supply combined with changes in crop yields. (simulation SC4-Flexible)

For this report, only a subset of scenarios has been used, i.e S1 to S4, SC1 to SC4 and SC1-W20 to SC4-W20)

Impacts on Growth

The impacts of droughts (shocks) and water scarcity (long-term stressor) on the economy are different but could reinforce each other. As highlighted above (Figure 2, Figure 3 and Figure 4 as well as Box 2), droughts have become a major source of macro-economic volatility, explaining more than one third of the variance of Morocco´s output. That said, while the economy is adversely impacted during a dry year, agricultural production tends to “rebound” the following year and return to its usual level. However, a permanent reduction in water resources represents a constant threat for the national income in a medium- to long-run time frame. Droughts and water scarcity are interlinked and reinforce each other, as seen during the first quarter of 2022, the impacts of the drought were made particularly challenging to manage given the low level of filling rates in most of the dams across the territory.

Water scarcity, combined with climate change, could reduce the GDP by up to 6.5 percent. Water scarcity is projected to have significant adverse impacts across all sectors of the economy. The Table 2 below shows that a reduction in water availability could reduce the GDP by up 5.3 percent: while agriculture sector would suffer the most (with a drop of up to 7.9 percent of GDP), non-agricultural sectors would also be significantly affected[39]. The negative impact on the economy would be further exacerbated by the changes in crop yields induced by climate change, with a drop in real GDP of up to 6.5 percent: interestingly, the changes in crop yields would also increase the negative impacts on non-agriculture sectors given the forward and backward linkages between agricultural and non-agricultural sectors in the Moroccan economy. The introduction of water use efficiency (WUE) practices in agriculture would only partially offset the negative impacts of water scarcity and climate change on GDP: however, it is worth noting that the benefits of WUE practices increase at an increasing rate as the rate of water scarcity grows. Overall, under all scenarios, agricultural sector is projected to suffer the most, reflected by a drop of its share in the GDP from the 13 percent basis to below 11 percent.

[38] Based on the assumption that productivity of rainfed crops versus irrigated crops will drop by 5 percent.
[39] Water resources also represent a critical production factor for sectors such as manufacturing and services sectors.

Table 2: Changes in GDP under different water scarcity scenarios

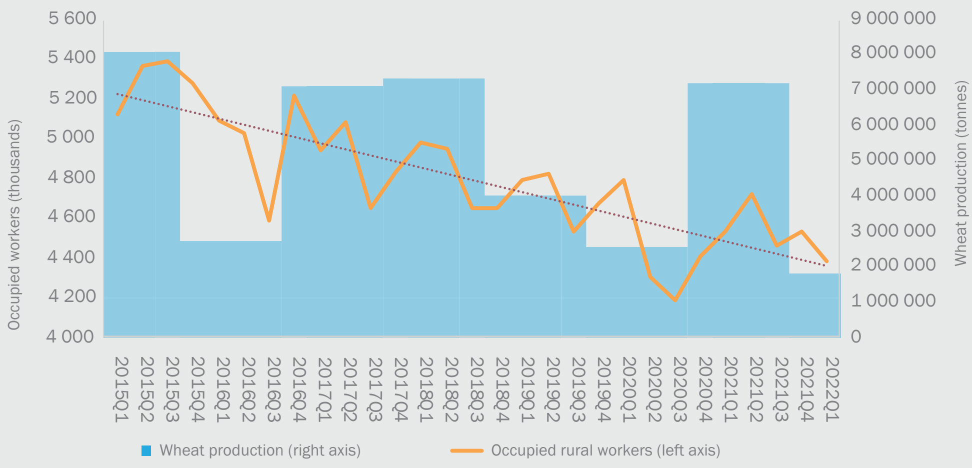
		Reduction in water supply (percentage)			
Examined variable	Examined case	10	15	20	25
Change in Agriculture GDP (percentage)	S1 à S4	-2,9	-4,5	-6,2	-7,9
	SC1 à SC4	-7,1	-7,5	-8,2	-9,3
	SC1-W20 à SC4-W20	-7,8	-7,6	-7,6	-7,8
Change in non-Agriculture GDP (percentage)	S1 à S4	-1,9	-2,9	-4,0	-5,2
	SC1 à SC4	-4,0	-4,5	-5,2	-6,2
	SC1-W20 à SC4-W20	-3,5	-3,7	-4,0	-4,5
Change in real GDP (percent-age)	S1 à S4	-1,9	-3,0	-4,1	-5,3
	SC1 à SC4	-4,3	-4,8	-5,5	-6,5
	SC1-W20 to SC4-W20	-3,8	-4,0	-4,3	-4,8

Source: GTAP-Bio-Water modeling exercise, extracted from "Water Scarcity in Morocco" report

Impacts on Jobs and Domestic Migration

Rural livelihoods are particularly vulnerable to droughts and water scarcity. The agriculture sector employs nearly 30 percent of the national workforce but more than 80 percent of the rural population[40]. Rural livelihood is intrinsically linked to agriculture, with a large majority of the rural population relying on agriculture, mostly rainfed, for income and food. As shown in Figure 16, the behavior of the rural labor market has followed two clear patterns in recent years: (i) an overall downward trend in levels[41]; (ii) large fluctuations correlated with climatic conditions (proxied by cereal production), with employment levels below the trendline when rainfed crops are poor (droughts) and vice versa. In this context, increasingly frequent droughts and structural water stress can be expected to continue shrinking rural job opportunities in the decades to come.

Figure 16: Rural labor markets and cereal production



Source: World Bank staff with data from FAO-Stat and HCP

40 About 70 percent of Morocco's farms smaller than 5 hectares.

41 This downward trend is reflected in the negative jobs multiplier that has characterized agricultural value-added growth in recent decades (Source: "Job Diagnosis in Morocco" prepared jointly by the World Bank and the HCP).

The decline in water supply would negatively impact the labor demand across sectors, with the biggest impact in agriculture sector and for unskilled people. The simulations conducted with the GTAP-Bio model suggest that a reduction in water supply would drop labor demand at a considerable rate across the entire economy (at 6 percent and 5.4 percent for unskilled and skilled labor respectively). Together with the changes in crop yields due to climate change, it could drop the demand for unskilled labor in agriculture by almost 10 percent. Other sectors would also be adversely impacted, but to a lesser extent (see Table 3). Labor intensity in irrigated schemes tends to be lower than in rainfed areas which means that WUE practices would have a limited capacity to mitigate the drop in labor demand in agricultural activities and would overall provide more job opportunities for skilled people. As Morocco is already struggling to absorb the growing working age population, water scarcity combined with climate change could further exacerbate its labor market challenges, characterized by high levels of inactivity, particularly among women and the youth, who tend to structurally be particularly more vulnerable (see Box 5)[42].

Table 3: Changes in labor demand (skilled and unskilled) under different water scarcity scenarios

			Reduction in water supply (percentage)			
Examined variable		**Scenarios**	**10**	**15**	**20**	**25**
Agriculture Activities	Changes in demand for unskilled labor (percent-age)	S1 à S4	-3,1	-4,8	-6,6	-8,4
		SC1 à SC4	-7,3	-7,8	-8,6	-9,7
		SC1-W20 à SC4-W20	-7,4	-7,3	-7,4	-7,7
	Changes in demand for skilled labor (percent-age)	S1 à S4	-2,2	-3,4	-4,6	-6,0
		SC1 à SC4	-4,5	-5,0	-5,8	-6,8
		SC1-W20 à SC4-W20	-4,2	-4,3	-4,5	-5,0
Non Agricultural Activities	Changes in demand for unskilled labor (percent-age)	S1 à S4	-1,9	-3,0	-4,1	-5,3
		SC1 à SC4	-4,0	-4,6	-5,3	-6,3
		SC1-W20 à SC4-W20	-3,5	-3,7	-4,0	-4,5
	Changes in demand for skilled labor (percent-age)	S1 à S4	-2,0	-3,0	-4,2	-5,4
		SC1 à SC4	-4,1	-4,7	-5,5	-6,4
		SC1-W20 à SC4-W20	-3,6	-3,8	-4,2	-4,7
All economic activities	Changes in demand for unskilled labor (percent-age)	S1 à S4	-2,2	-3,4	-4,6	-6,0
		SC1 à SC4	4,7	-5,2	-6,0	-7,0
		SC1-W20 à SC4-W20	-4,3	-4,4	-4,7	-5,2
	Changes in demand for skilled labor (percent-age)	S1 à S4	-2,0	-3,0	-4,2	-5,4
		SC1 à SC4	-4,2	-4,7	-5,5	-6,5
			-3,6	-3,8	-4,2	-4,7

Source: GTAP-Bio-Water modeling exercise, extracted from "Water Scarcity in Morocco" report

42 In the primary sector, both women and youth are exposed to vulnerable conditions, with respectively about 73 percent and 60 percent of unpaid labor.

Box 5: Gender-Differentiated Impacts of Climate Change: A Review of the Literature

While climate change and shocks are gender-neutral, their impacts are not. Due to existing gender disparities in Morocco, women suffer greater exposure and greater vulnerability, and have a more limited level of preparedness and coping capacity compared to men in case of disaster. These limitations emerge, among other factors, from Moroccan women's limited access to information such as early warning systems, as well as from post-disaster interventions.

A 2013 review in the commune of Boudinar shows that (i) women are more likely than men to lose their jobs during dry events (the main driver being that they work predominantly in the informal sector, which makes them more vulnerable to labor adjustments in response to shocks); (ii) during periods of drought, women's workload rises (mainly to ensure access to water); and (iii) during and after flood events, women are mobilized to evacuate rainwater from their homes while men are repairing and fitting out roofs and furniture (Khattabi, 2013).

A study conducted in the regions of Tangier and Tinghir finds that farm households rely on internal migration to mitigate the consequences of climate change (Van Praag, 2021). Specifically, this study shows that men are more likely to migrate first to other localities to seek work in times of drought, often leaving the women at home even though the women also want to migrate. A qualitative study focusing on these regions finds that a high prevalence of women relative to men in the agricultural sector makes them more vulnerable to the effects of climate change, such as drought and land degradation (Van Praag, 2022). In these regions, the decrease in agricultural productivity due to climate change leads to a reduction in their income and a decrease in their decision-making power in the household.

Overall, climate change is expected to heighten existing gender-equality gaps in employment and income levels; women's access to and control over productive assets and natural resources; their access to services, skills, and capacity; and their mobility, as well as agency and decision-making power.

Losses in agricultural job opportunity could fuel migratory phenomenon to urban centers. On one side, water scarcity, compounded with crop yield changes due to climate change, would accelerate the observed downward trend of job employment in agriculture sector. On the other side, the increase in agricultural value added registered over the past two decades has come with a negative jobs multiplier.[43] As a result, and unless the losses in primary sector are compensated in alternative opportunities in rural areas (along the agriculture value chains or through other sectors such as tourism), rural people in working age could face challenging conditions, pushing some of them to opt for migration to urban areas. The Groundswell 2.0 report projects that, in Morocco, up to 1.9 million people (representing 5.4 percent of the total population) could migrate out of rural areas by 2050 (see Box 6). Rural areas with a predominance of rainfed agriculture and with projected declines in water availability (combined or not with a decline in crop productivity) would witness the most out-migration, with hotspots concentrated in the central foothills, including around Marrakech, and on the west and southwest coast around Casablanca, Safi, and south of Agadir to Tiznit [44].

[43] Source: "Job Diagnosis in Morocco" prepared jointly by the World Bank and the HCP. This does however does not take into account seasonal jobs.
[44] Morocco has put in place various programs, including small-scale public works for water management, to retain population in rural areas, offering job opportunity while supporting local water management solutions.

Box 6: A looming crisis of Climate Migration – Groundswell 2.0 report[45]

The Groundswell report published in September 2021 projects the trends in domestic migration driven by climate change. It uses three different scenarios as a combination of development pathways (Shared Socioeconomic Pathways: SSP2 as moderate development and SSP4 as unequal development) and GHG emission pathways (RCP 2.6 as low emissions and RCP 8.5 as high emissions): (i) a pessimistic reference scenario (unequal development and high emissions); (ii) more inclusive development (moderate development and high emissions) and (iii) more climate friendly (unequal development and low emissions).

Climate change is projected to spur out-migration from rural areas where water availability will decline. In Morocco (one of the three country cases) climate migration is projected to increase during the coming three decades, rising to 2050 across the three scenarios, albeit with considerable differences (as shown in the below Figure 18 and Figure 17): the number of climate migrants could be as high as 1.9 million (representing 5.4 percent of the total population) under pessimistic reference scenario; in the more inclusive development scenario, the projection is 1.5 million (4.0 percent of the total population), and in the more climate-friendly scenario, it is 0.5 million (1.3 percent of the total population).

Figure 17: Projected number of internal climate migrants in Morocco under three scenarios, 2020-50

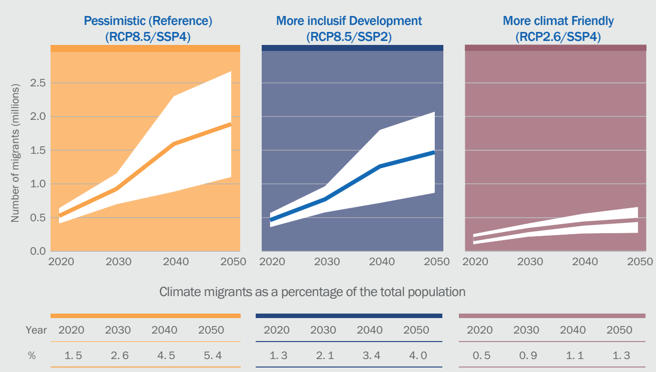
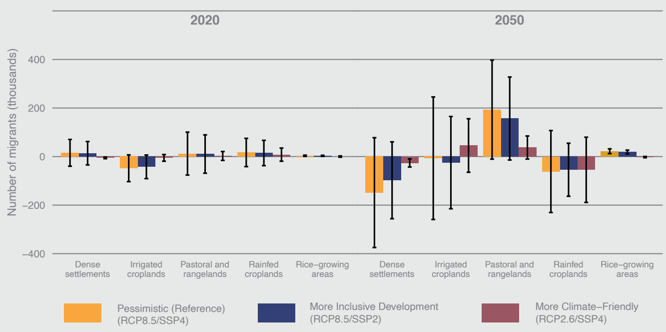


Figure 18: Projected net climate migration in and out of livelihood zones in Morocco under three scenarios, 2020-50



Source: World Bank, Groundswell 2:0, 2021

Nota: The scenarios are based on combinations of two Shared Socioeconomic Pathways—SSP2 (moderate development) and SSP4 (unequal development)—and two Representative Concentration Pathways —RCP 2.6 (low emissions) and RCP 8.5 (high emissions).

[45] See “Groundswell: Acting on Internal Climate Migration” report

Impacts on Trade of Food Products and Food Security

Increased pressure on water supply could put Morocco's agricultural trade at risk. On one side, droughts increase the dependency on cereal imports to compensate the shortage of domestic production, potentially threatening the national food security[46]. On the other hand, the decline in water supply could deteriorate the agricultural trade balance, notably by reducing a large chunk of agricultural exports. The simulations run with the GTAP-Bio-Water show that the combined drop in water supply by 25 percent with climate change impacts could make net exports drop by US$891 million per year (at 2016 prices), which would correspond to about 24.7 percent of agricultural exports, and 3.5 percent of total merchandise exports, respectively[47] (see Table 4). Improvements in WUE eliminate only a small portion of the reduction in net exports of food items. In short, as production of agriculture drops, Morocco is expected to export less to, and import more and from other countries. Although water scarcity and yield changes jointly decrease the net exports of all agricultural and food products of Morocco, a large portion of this reduction (more than 50 percent across the different scenarios) falls on vegetables and fruits. This is because these crops are the main exporting crops of Morocco, and they jointly consume the largest portion of water for irrigation.

Table 4: Changes in Trade Balance of Food Items under different water scarcity scenarios

		Reduction in water supply (percentage)			
Examined variable	Scenarios	10	15	20	25
Changes in trade balance of food (US$, millions)	S1 à S4	-223	-345	-475	-611
	SC1 à SC4	-679	-728	-797	-891
	SC1-W20 à SC4-W20	-612	-627	-651	-692

Source: GTAP-Bio-Water modeling exercise, extracted from "Water Scarcity in Morocco" report.
Note: Food items include crops, livestock, and processed food.

Impacts on Financial Stability

Droughts can have strong impacts on the stability of the banking sector through direct and indirect transmission channels (see Table 5). The impact of climate change on the financial sector can be broadly categorized into two types of risks – (a) climate physical risks, which are financial risks stemming from the gradual and abrupt impacts of climate change; and (b) climate transition risk, which are financial risks which can result from the process of a low carbon transition prompted, for example, by unanticipated changes in climate policy, technology, or market sentiment. In the case of droughts, crop producers and livestock farmers could suffer direct economic losses arising from a decrease in crop yields. This could spillover and affect broader sectors that are connected to the agriculture sector through supply chain linkages (e.g., food processing sector and tourism). These losses could indirectly lead to adverse socioeconomic impacts. For example, it could lead to higher unemployment and loss of income.

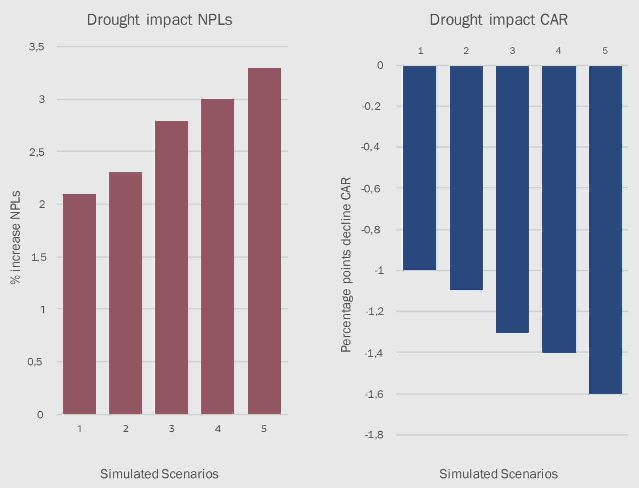
[46] Morocco is a net importer of grains and volumes of grain imports are negatively correlated to rainfalls and domestic production For example, when Morocco's wheat production plummeted to 2.7 million tons in 2016, from 8.1 million tons in 2015, the country's wheat imports doubled to 6.3 million tons in 2016, from 3.2 million tons in 2015. Barley production and imports in Morocco also show a similar pattern but to a smaller extent.
[47] Based on US$3.9 billion and US$27.7 billion of Morocco's agricultural and total exports in 2020.

Table 5: Overview of physical risks transmission channels for a drought

Direct Impacts	**Exposure to agricultural sector.** Economic losses incurred by crop producers and livestock farmers can lead to non-repayment of loans (credit risk) and reduce banks' profitability.
	Exposure to agro-industrial and other affected sectors. Losses in the agriculture sector are likely to spill over to other sectors through input-output linkages, which are particularly strong to the agro-industrial or food processing sector (about 27 percent of industrial output and 5 percent of GDP). This can lead to non-repayment of loans (credit risk), unpredictability of the equity and debt markets (market risk) and strains on banks' liquidity for acute events (liquidity risk).
Indirect impacts	**Socioeconomic channels.** Droughts increase unemployment and can trigger internal migrato-ry flows, which can reduce households' debt servicing capacity (credit risk) and lead to deposits withdrawals (liquidity risks).
	Macroeconomic channels. Droughts can trigger inflationary pressures, potentially affecting the exchange rate and forcing the central bank to increase its policy rate. Higher interest rates would affect the valuation of banks' investment portfolio and exchange rate volatility can increase market risk and credit risk for non-hedged borrowers with FX denominated loans.

A significant share of banks agriculture lending is in areas which are prone to droughts. Large parts of Morocco may see a significant reduction in agricultural output: more 60 percent of Morocco's provinces are estimated to see a drop in cereal yields by at least 10 percent over the next decade (RCP8.5, 2030s) with the regions of *Tiznit, Sidi Ifni*, Settat and *Berrechid* being projected to be the most exposed to droughts. These provinces receive roughly three-quarters of banks' agricultural loan portfolio outside the major metropolitan areas[48] and account for almost 80 percent of total bank loans to the food processing sector. As shown in Figure 19, the different drought scenarios could result in a system-wide increase in non-performing loans (NPLs) ranging between 2.1 ppts and in a decline in the capital adequacy ratio (CAR) that would range from 1.0 ppts to 1.6 ppts. These system-wide impacts hide important differences across institutions, with the balance sheets of those specializing in the agricultural sector undergoing significantly larger adverse effects, and potentially needing to be recapitalized (CAR below 10 percent).

Figure 19: Stress Testing on Physical Risks related to Droughts



Scénarios considérés :

SD1 : 3 years long historical drought
SD2 : RCP 4.5 drougth scenario occuring in 2030
SD3 : RCP 4.5 drougth scenario occuring in 2050
SD4 : RCP 8.5 drougth scenario occuring in 2030
SD5 : RCP 8.5 drougth scenario occuring in 2050

Note: This assessment incorporates a macro-modelling exercise to simulate the impact of the simulated catastrophic scenarios on the capital stock and jobs. The underlying assumption is that the destruction of capital stock in the agricultural sector results in a proportional share of agricultural loans turning non-performing, and that the job losses associated with each scenario result in a proportional share of consumer and mortgage loans turning non-performing.

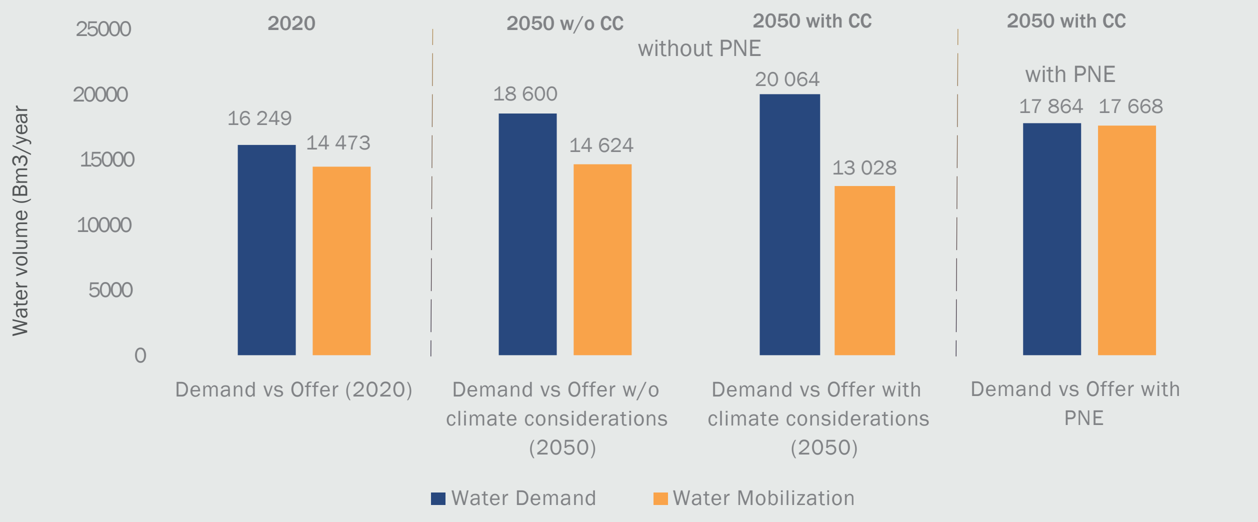
[48] Loans in Casablanca, Rabat, Fes and Tangir are excluded.

Recommendations to Tackle Water Scarcity and Droughts

3.1. An Ambitious Plan to Tackle Water Scarcity and Droughts

The 2050 PNE represents an ambitious infrastructure plan that has been designed to tackle the water demand-supply gap over the decades to come. As indicated above, the water demand-supply gap is currently estimated at 1.8 billion m^3/year at the national level and is projected to reach 7 billion m^3/year by 2050 when taking into account the effects of climate change. The 2050 PNE lists a series of mostly engineering solutions to close this deficit. On one hand, the PNE aims at reducing the water demand[49] by 2.2 billion m^3 /year by 2050, by (i) reducing water losses in transport and distribution of potable water (up to 0.4 billion m^3/year) and (ii) saving 1.8 billion m^3/year of water in the agriculture sector through modernized irrigation. On the other hand, the PNE plans for an increase of water mobilization by 4.6 billion m^3/year by 2050 through: (i) dam construction and interconnections (3 billion m^3/year), (ii) desalination (1 billion m^3 /year); (iii) wastewater use (0.3 billion m^3/year); and (iv) rainwater harvesting (0.3 billion m^3 /year). However, should the PNE actions be fully implemented, leading to the expected results by 2050, the increased sustainable water supply level would be 17.6 billion m^3/year[50], while the demand would be 17.8 billion m^3/year, thus leaving a residual water deficit of about 0.2 billion m^3/year. See Figure 20).

Figure 20: Projected water deficit over the period 2020-2050 period (with and without climate consideration and with and without PNE interventions)



Source: Authors' calculations (based on the PNE, 2021)

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[49] The soon-to-be-published report "The new normal of allocating water scarcity" from the World Bank points out to the "counterintuitive effect" the pitfalls of the engineering solutions to water demand management that can end up leading to a higher water demand.

[50] The PNE projects that sustainable water resource supply levels will decrease from 14.473 to 13.028 billion m^3/year by 2050 due to reduced dam storage capacity caused by sedimentation, decreased run-off, and declined groundwater recharge due to climate change.

3.2. Potential Pitfalls of the 2050 PNE

The current version of the PNE mostly focuses on "engineering solutions" which could further undermine its capacity to fully deliver on closing water gap. The PNE almost exclusively on focuses on engineering supply and demand actions[51]. Soft measures, such as communication and awareness raising or water resource management and ecosystem preservation, only represent a very small fraction of the overall PNE (about 1.3 percent of the total budget). There is however a growing literature warning about counterintuitive impacts of engineering supply and demand actions leading to develop an economy that increases its level of water dependency and fails to reduce the pressure on water resources (See Box 7). Hence when not paired with policy measures, that engineering supply and demand actions do not achieve expected results when implemented without consideration to policies aiming at controlling water demand growth, allowing for aquifer recharge, and preventing the depletion of the non-renewable groundwater. Thus, in the absence of water demand management policies, even if all the investments of the PNE are implemented, the PNE implementation will likely not result in closing the demand-supply gap by 2050.[52]

Box 7: Counterintuitive Impacts of Engineering Solutions

The recent research has shed light on counterintuitive dynamics that can explain why "engineering supply and demand actions" alone tend to fail in reducing the pressure on water demand. Below three of these counterintuitive impacts are described below:

The supply-demand cycle counterintuitive effect leads to a higher water demand. Supply-demand cycles describe instances where increasing water supply generates higher water demand, which eventually offset the initial benefits of engineering supply solutions and aggravate water scarcity. It also leads to lock-in unsustainable water resource use and negative externalities (financial, social, and environmental).

The "reservoir effect" (or overreliance on water infrastructure) counterintuitive effect is associated with the expansion of water supply. The belief that water will always be available reduces incentives for adaptive actions at individuals or community levels to prepare for a period of water shortages or droughts. The reservoirs provide extended periods of abundant water supply and generate increasing dependence on water infrastructure, increasing vulnerability and economic damage when water shortages eventually occur. The reservoir effect can also be explained as a safe development paradox: increased levels of safety can paradoxically lead to increased damage. This paradox is widely documented in flood risks. The reservoir effect hypothesizes that reservoirs can reduce the authorities' effort to develop other adaptation measures and increase economic and social vulnerability.

The water efficiency paradox counterintuitive effect is associated with a higher water consumption. The rebound effect of Jevons paradox explains this paradox. A growing number of water-scarce regions worldwide are promoting water conservation technologies to increase physical irrigation efficiency, commonly defined as the ratio of water consumption by the crops in a field to the water diverted from a water source. The conventional wisdom is that higher physical irrigation efficiency will reduce the demand for scarce water resources, conserving water and enhancing agricultural productivity and income on-site. But most water conservation efforts on farms, and claims of water-saving potential, have focused solely on changes in the volume of water withdrawn or applied to farm fields, neglecting the volume and fate of return flow back into the original water source, creating misleading impressions of water benefits within the overall irrigation network or basin. More efficient irrigation application can result in greater net consumptive use, ultimately lessening the volume available for subsequent uses. Dionision (2020) conducted a comprehensive review of the theoretical and empirical literature on water conservation technologies that includes more than 230 studies. The review concluded that if the ultimate objective is water-saving (and possible transfer to other users), it is essential to concomitantly implement water demand management policies such as quota allocation systems.

Source: Extract from the World Bank report "The new normal of allocating water scarcity: Adapting Water Resources Management and Services to the Changing Future" Phase 2. To be shortly published

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[51] The expression "engineering supply and demand actions" refers to engineering supply actions: reservoirs, desalination, treated wastewater reuse, and rainwater harvesting; and engineering demand actions: reduction of leakages, and localized irrigation.

[52] Only a very small fraction of the PNE intervention (representing about 1.3 percent of the total budget) corresponds to soft measures, spanning from communication to groundwater resource management and ecosystem preservation.

Besides, the use of a single climate change scenario in the PNE might understate or overstate the magnitude of the climate change threat. The PNE considers a maximum precipitation reduction of 10 percent, translated to an equivalent reduction of 10 percent of "mobilized" resources (i.e., water resources available for water supply). This does not account those reductions in surface water-flows available for abstraction (use) are likely to be larger than just the fraction of reduced precipitation. The fifth IPCC multi-model studies (climate-hydrology) indicate that future precipitation reductions could be 15%-25% in the North of Morocco (under RCP 8.5 for 2100). Empirical data reveals that reductions in precipitation coupled to higher temperatures and evaporation rates usually lead to reductions in river flows that are higher than the drop in rainfall. Therefore, the single scenario of reduced precipitation and groundwater available in the PNE is likely optimistic and could result in plans that do not meet desired or expected service levels. Given the significant uncertainty in future precipitation and its impact on allocable water, the PNE could be improved by adding climate change scenarios.

Maintenance should be enhanced to ensure water infrastructure operate at an optimal level. As mentioned in the first section of the report, many dams in Morocco are currently operating at a suboptimal level because they have not received the required level of maintenance, not always benefitting from the accompanying management measures in upstream watersheds to reduce the erosion and the associated risks of siltation[53]. Similarly, the insufficient levels of O&M contribute to substantial losses in the transport and distribution networks. As Morocco embarks on a large infrastructure plan under the PNE, it needs to adjust the design and devote the necessary level of financial resources to O&M in order to fully use their potential during their entire lifetime and reduce the losses along the distribution network. Using nature-based solutions for dam/reservoir management has proven to be a cost-effective solution and the current program *"Forêts du Maroc"* represents an opportunity to bring this type of solution at scale. Another solution that Morocco should contemplate relates to the recharge of aquifers, that needs to be carefully deployed to avoid any contamination risks.

3.3. Tradeoffs in the Use of Public Resources

Investing in water infrastructure is seen as an efficient way to reduce the adverse impacts of both droughts and water scarcity. Morocco has traditionally managed the water scarcity challenge through infrastructure solutions (dams and modernized irrigation systems). In its 2022 report "Feeling the Heat: Adapting to Climate Change in the Middle East and Central Asia", the IMF estimates that investing in climate adaptation infrastructure would improve the resilience of the Moroccan economy to droughts, reducing GDP losses by almost 60 percent (compared to an equal size investment in standard infrastructure). It also shows that a more muted decline in GDP would be beneficial for the debt-to-GDP ratio trajectory in the aftermath of the events. In that sense, the 2050 National Water Plan goes in the right direction as it represents an ambitious infrastructure plan to increase water mobilization and improve water productivity.

However, the PNE will absorb a large volume of public resources, which warrants a careful cost-benefit analysis of its different components given Morocco's fiscally constrained environment. The overall PNE is estimated to mobilize about USD 41 billion that would be mostly covered by public resources. Given the constrained fiscal space that Morocco inherits from the COVID-19 pandemics and the ambitious plans set in the New Development Model, an important policy question is whether a portion of the public resources expected to be committed for the PNE could have more economically beneficial alternative uses.

We thus use the MFMod model to address this question by simulating the impact of repurposing part of the investments contemplated by the PNE. Four scenarios are simulated in this exercise: two in which the resources freed by an incremental reduction in the investments that are planned in PNE to increase water supply are used to reduce debt; and two scenarios in which these resources are used to finance other productive investments. These macroeconomic simulations assume that the reduction in infrastructure investment (new water mobilization infrastructure planned under the PNE) would result in water rationing only on irrigated agriculture, given that the

[53] The annual operating and maintenance costs are assessed in proportion to the investment costs of the project, at a level of 0.5% of the total cost of the project. However, the lack of staff in charge of the O&M constitutes a challenge in terms of planning and monitoring.

authorities are fully committed to ensure that water demanded by the other sectors of the economy will always be met first. The scenarios contemplate a 10 and 25 percent reduction in the water flows that are made available to irrigated agriculture. For the sake of simplicity, it is assumed that investment is proportionally related with the increase/reduction in water supply[54]. See Box 8.

Box 8: Modeling Approach to Assess Tradeoffs associated to Water Infrastructure Investments

This exercise consists in linking the macroeconomic results derived from the GTAP-BIO-W model (notably the impact of the reduction in water supply on the agriculture output) with different scenarios on PNE investments for water mobilization. We then use the MFMod model to assess their impacts on GDP, consumption, and investment.

The baseline scenario corresponds to the full implementation of the PNE (eq. to US$41 billion). Under this baseline, it is assumed that the entire demand for water (from all sectors) will be fulfilled. We then assess the reductions of the PNE investments that would correspond to a 10 percent and a 25 percent reduction in water supply for irrigation purposes. Morocco has set a guiding principle that the water demand for all sectors except agriculture would be systematically fulfilled (and that the water demand for irrigation would be accordingly adjusted based on the water availability – adjustment parameter-). Following this principle, we look at the demand for irrigation (for large-scale irrigation, small-medium irrigation schemes and private irrigation, excluding the demand that could be covered by underground water). By 2050, the PNE estimates that this cumulative demand would reach 12.7 billion m^3 (3.3 billion m^3 would come from underground water) to which we would apply a reduction of 10 percent and 25 percent. The Table 6 describes the underlying assumptions used to determine the level of reduction of the PNE investments planned for additional water mobilization. These levels of reduction are then paired with the corresponding scenarios under the GTAP-Bio-Water model and the associated results in terms agriculture GDP deviation from baseline.

[54] See Background note "Deep Dive on Water Scarcity and Droughts" for a detailed presentation of the modeling approach.

Table 6: Assumptions for the modeling

	Reduction water supply	Water mobilization for irrigation (except groundwater)		
		Water demand (BCM)*	Water supply (BCM)	Percentage of the water Mobilization infrastructure under
Baseline	0%	12 700	12 700	0%
S1 Debt	10%	12 700	11 430	30%
S2 Debt	25%	12 700	9 525	74%
S1 Investment	10%	12 700	11 430	30%
S2 Investment	25%	12 700	9 525	74%
	Investments			
	Description	Total (M USD)	Change with baseline (M USD)***	Alternative use of investments
Baseline	All PNE infrastructure	41 375	0	None
S1 Debt	PNE menus 30% of planned mobilization inf.	36 699	-4,676	Debt Reduction
S2 Debt	PNE menus 74% of planned mobilization inf.	29 684	-11 691	Debt Reduction
S1 Investment	PNE menus 30% of planned mobilization inf.	36 699	-4 676	Investment reallocation
S2 Investment	PNE menus 74% of planned mobilization inf.	29 684	-11 691	Investment reallocation
	Corresponding scenario GTAP-BIO	Agricultural GDP dev baseline (%)		
Baseline	Baseline	0		
S1 Debt	S1	-2,93		
S2 Debt	S4	-7,94		
S1 Investment	S1	-2,93		
S2 Investment	S4	-7,94		

* Water demand does not take into account demand for underground water
** the PNE foresees in an increase of 4.285 billion m3 in water mobilization
*** Investments for additional mobilization are estimated at US$15.78 billion

Summary of the scenarios

Baseline corresponds to the full implementation of the National Water Plan (PNE)
S1 Debt: reduction in PNE investments on additional water mobilization infrastructure corresponding to a 10 percent reduction in water supply for irrigation, freed resources used for debt reduction (fiscal consolidation).
S1 Investment: reduction in PNE investments on additional water mobilization infrastructure corresponding to a 10 percent reduction in water supply for irrigation, freed resources used for alternative productive investment.
S2 Debt: reduction in PNE investments on additional water mobilization infrastructure corresponding to a 25 percent reduction in water supply for irrigation, freed resources used for debt reduction (fiscal consolidation).
S2 Investment: reduction in PNE investments on additional water mobilization infrastructure corresponding to a 25 percent reduction in water supply for irrigation, freed resources used for alternative productive investment.
We then use MFMod to conduct macro-simulations to capture the tradeoffs associated with water infrastructure, comparing the impacts of different investment pathways defined in terms of their scale (as percentage of reduction in water mobilization) and financing sources (debt vs. investment substitution).

The simulations conducted suggest that the redeploying water infrastructure investments to other uses would not elicit positive macroeconomic responses. In all four scenarios, GDP, consumption, and investment fall below the baseline, indicating that full completion of the PNE investments is the pathway that would have the most positive aggregate impacts in terms growth, consumption and investment (see Table 7). Unsurprisingly, the one macro variable that evolves positively is the level of debt under the two scenarios where freed investment is used to reduce the budget deficit (S1-debt and S2 debt). However, given the adverse impacts that this option would have on GDP, investment, and consumption, it does not appear to be the most appropriate one to create fiscal space.

Table 7: Macroeconomic Simulations – PNE Partial Redeployment

	GDP Deviation from Baseline (*)			Consumption Deviation from Baseline (*)			Investment Deviation from Baseline (*)			Debt Deviation from Baseline (*)		
	2030	2040	2050	2030	2040	2050	2030	2040	2050	2030	2040	2050
S1 Bebt	-0.04%	-0.19%	-0.48%	-0.07%	-0.28%	-0.56%	-0.49%	-0.54%	-0.73%	-2.46%	-3.48%	-2.90%
S1 Investment	0.01%	-0.09%	-0.38%	0.01%	-0.12%	-0.40%	0.04%	-1.44%	-0.64%	0.12%	0.16%	0.16%
S2 Bebt	-0.12%	-0.55%	-1.32%	-0.20%	-0.78%	-1.51%	-1.28%	-0.19%	-1.99%	-6.14%	-8.67%	-7.25%
S2 Investment	0.00%	-0.31%	-1.07%	0.00%	-0.39%	-1.14%	0.05%	-0.60%	-1.79%	0.30%	0.42%	0.43%

Source: own calculations using intermediate results of the GTAP-Bio model and the MFMod model.

Maximizing the participation of the private sector in this effort would still be desirable. The modeling exercise presented above goes in the direction that investing in water infrastructure is a good use of public -scarce- resources given the significant impact water rationing would have on the economy. That, said, it would still be desirable to attract some private financing to support such effort. And the PNE foresees that some key infrastructure could be shouldered by the private sector (desalination and wastewater treatment and some irrigation investments). However, the PNE does not set a clear roadmap to attract private financing, with the right incentives to be in place for this financing to materialize[55]. Additionally, and beyond the financing of capex, the private sector could play a key role in the operation & maintenance of the infrastructure, bringing innovation and increasing efficiency of the water systems (NRW, leaks/losses, repairs…).

[55] The PPP Law 86-12 issued in 2014, revised by Law 46-18 in 2020, could be used for desalination projects. Hence, there may be no need to develop specific regulations for awarding desalination concessions as required by the Water Law 36-15. Likewise, the regulation of the award desalination authorizations to private users, contemplated under the Water Law 36-15, may not be required since the exploitation of marine resources shall be regulated by the Coastal Law 81-12 and other laws and regulations related to the public maritime domain. Finally, the regulation of effluent discharges to the ocean foresaw under the Coastal Law 81-12 should be expedited, including the conditions under which brine discharge permits renewals could be denied.

3.4. Complementary Soft Measures

Lessons from the past decades show that engineering solutions are likely insufficient to close the water-demand gap and need to be complemented by water demand policies. There is growing literature warning that engineering supply and demand actions do not achieve expected results when implemented without water demand management policies (see Box 7). In line with the recommendations put forward by NDM report, Morocco should consider designing policies that would maintain water demand under control and in line with the renewable water supply level. The following policies should be considered:

- **Improve water resource planning and allocation.** It is critical to ensure an allocation system adapted to water scarcity and plan water uses based on water availability and water sources that the country can further mobilize or augment within its fiscal limits. The limitation in the water availability impacts some users more, and a system of compensation often becomes necessary with the increased scarcity.

- **Improve water sector governance:** Setting the right governance model in the water sector is critical to help manage competing demands from many sectors. There is no clear blueprint or off-the-shelf solution for managing trade-offs in the allocation of scarce water resources across sectors; each country has to pave its own reform policy path. Morocco's Economic, Social and Environmental Council (CESE) has published a report on water governance[56] that calls for a governance model that would ensure that decisions about water resource management are made in a way that optimizes the overall socioeconomic outcomes of the country, and that aligns with the development model set for Morocco[57]. In particular, it highlights the need for a strong national entity that is able to arbitrage trade-offs that could arise from the various actors (and sectors) that have competing demands. The governance model should also provide for a level of flexibility with a clear set of principles that will be helpful in navigating evolving situations and adapting to them. Recent research from the World Bank[58] shows that besides having a strong central entity that can set the principles for water resource planning and allocation (using a science-based approach and robust information), it is important to empower local entities and foster a decentralized approach. Decentralizing the decision-making process related to water resource management allows for better capturing local specificities, but also generating trust among stakeholders, which in turn increases their adherence to new rules. The aquifer contracts/participatory management contracts, launched in several regions (Souss-Massa (Chtouka), Errachidia (Boudnbib), Settat (Berrechid) and Fez-Meknes (Saiss)), are a key tool to stimulate such an approach. The Water Basin Agencies (or ABHs) are well positioned to support a decentralized approach to water resource management, but in order for this to materialize, they will have to be reinforced. Also, for increases in tariffs to be acceptable to users, it is crucial to ensure that the increase also comes with an adequate level of service delivery. In Morocco, some of the experiences in decentralizing the operation and maintenance of irrigation water schemes to water users' associations (WUAs) have proven to be a particularly efficient way to help users define appropriate service levels, water charges, and water allocation.

- **Value water better to reflect its scarcity.** Determining water's value is a complex exercise given the multiple water uses and the diverse views on the value of the water[59]. To address this challenge, Morocco should consider implement economic instruments to reflect water scarcity while safeguarding access for poor households, farmers, and the environment. In line with the NDM recommendations, an adjustment to water tariffs could be an appropriate tool to incentivize a

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[56] CESE 2014. « La gouvernance par la gestion intégrée des ressources en eau au Maroc : Levier fondamental de développement durable ».
[57] To that effect, the NDM report also highlights the need to adjust the governance of the water sector and mentions the creation of a National
[58] World Bank, soon to be published: "The Economics of Water Scarcity in the Middle East and North Africa: Institutional Solutions"
[59] Water is a regulated commodity without a free market and, as such, it is difficult to define its value using market prices.

more rationale use of water resources, notably the use of groundwaters that are fast depleting. In that sense, the Private Irrigation should be the priority target to enforce this DPH fee[60] and revisit the pricing modalities (amount, possibility of using different tranches, etc.) to produce the desired effects.[61] The combination of the DPH fee increase with a system of tradable quotas could provide the level of flexibility to ensure the optimal water allocation amongst users. Increasing revenues from the DPH fee would also provide the ABHs with more resources that would allow them to fully perform their responsibilities, notably the one related to water police. They could also more carefully monitor the use of groundwaters and proactively address the issue of overexploitation.

- **Develop a national water accounting system, in a participatory manner.** Given the centrality of water resources to the Kingdom's economic and social development, Morocco could develop a robust and reliable data system to monitor the availability of water resources (surface, groundwater, and non-conventional) as well as water uses of different sectors. This would help decision-making in the field of water resources management, particularly with regard to the allocation system amongst different uses but also of investment planning.
- **Communication and awareness raising to change behaviors.** Any water reform process, and particularly changes in allocation and pricing, needs to be accompanied by a communication campaign that would allow the different stakeholders to understand the rationale behind the proposed changes and gain their adhesion to the reform process. There are many positive examples around the globe (Israel, Brazil, South Africa, Cambodia to cite a few) where reforms were accompanied by well-sequenced communication and awareness raising campaigns: they show impatful results in terms of behavior changes. The current version of the PNE only includes a very shallow budget for communication and awareness raising (about US$5 million for the 2020-50 period, corresponding to less than 0.13 percent of the entire PNE budget).

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[60] As mentioned in Box 3/Chapter 1, a large part of private irrigation using ground water does not pay DPH fee.
[61] The Private Irrigation using groundwater covers around 620,000 ha, with an estimated water withdrawals probably around 4 to 4.5 billion of cubic meters per year.

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