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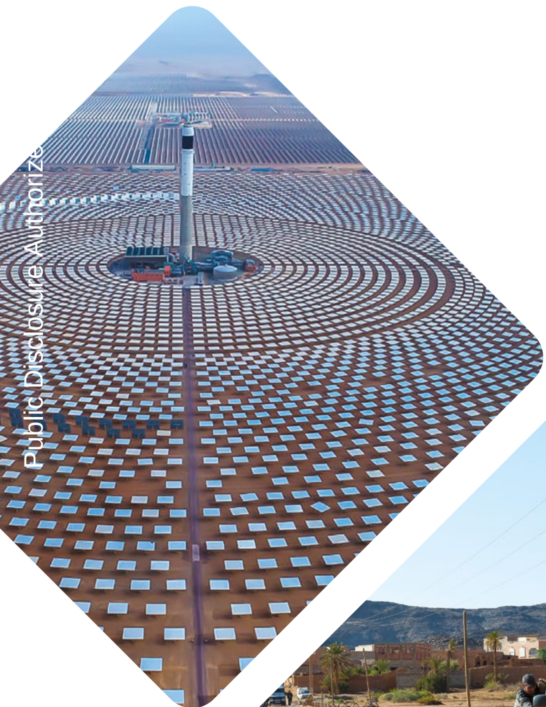
Supporting Early Action to Climate Shocks, Disasters, and Crises

DOUBLE TROUBLE?

Assessing Climate Physical and Transition Risks for the Moroccan Banking Sector

APRIL 2024



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BANK AL-MAGHRIB – WORLD BANK TECHNICAL ASSISTANCE PROGRAM

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1818 H Street NW
Washington DC 20433
Telephone: 202-473-1000
Internet: www.worldbank.org

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Cover design and layout: Kane Chong Sdn Bhd

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The joint World Bank–BAM task team responsible for this report was composed of Martijn Gert Jan Regelink (team lead), Reda Aboutajdine, Antoine Bavandi, Dorra Berraies, Thibault Bouessel du Bourg, Fabio Cian, Emma Dalhuijsen, Michaela Dolk, Olivier Masetti, Rachel Mok (World Bank), Hiba Zahoui, Nabil Badr, and Najwa Mouhaouri (BAM), under the guidance of Djibrilla Adamou Issa and Olivier Mahul (World Bank). The report and its cover were designed by Kane Chong.

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Abbreviations and Acronyms

AMMC	Moroccan Capital Market Authority
BAM	Bank Al-Maghrib
BAU	Business-as-usual
BCBS	Basel Committee on Banking Supervision
CAR	Capital adequacy ratio
CAT	Catastrophe
CBAM	Carbon Border Adjustment Mechanism
CDD	Consecutive dry days
CGS	Credit guarantee schemes
CSR	Corporate social responsibility
CO_2	Carbon dioxide
CORDEX-MENA	Coordinated Regional Climate Downscaling experiment for the Middle East and North Africa region
DNB	Deutsche Central Bank
DRM	Disaster risk management
DSGE	Dynamic Stochastic General Equilibrium
EBRD	European Bank for Reconstruction and Development
EITE	Emissions Intensity and Trade Exposure
EMDAT	The Emergency Events Database
EMDEs	Emerging markets and developing economies
EV	Electric vehicle
EU	European Union
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistics
FSEC	Fonds de Solidarité contre les Evènements Catastrophiques
GDP	Gross domestic product
GFC	Global financial crisis
GHG	Greenhouse gas
GPV	Gross production value
GTAP	Global Trade Analysis Project
ICAAP	Internal Capital Adequacy and Assessment Process
ICR	Interest rate coverage ratio
IEA	International Energy Agency
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
ISSB	International Sustainability Standards Board
JRC	Joint Research Centre
MAD	Moroccan Dirham
NAP	National Adaptation Plan
NDC	Nationally determined contribution
ND-GAIN	Notre Dame Global Adaptation Initiative
NFC	Nonfinancial corporate
NGFS	Network of Central Banks and Supervisors for Greening the Financial System
NPL	Nonperforming loan
PD	Probability of default
RCP	Representative Concentration Pathway
RISE	Regulatory Indicators for Sustainable Energy
ROA	Return on assets
ROE	Return on equity
RP	Return period
RWA	Risk-weighted assets
SFC	Stock-flow consistent
SREP	Supervisory Review and Evaluation Process
TCFD	Task Force on Climate-Related Financial Disclosures
VHI	Vegetation Health Index

Executive Summary

There is growing awareness globally about the potential impacts of climate change on financial stability. Climate-related financial risks can be broadly grouped into two categories: (i) climate physical risks, which are financial risks stemming from the gradual and abrupt impacts of climate change (primarily droughts and floods in the case of Morocco, as highlighted by the ongoing severe drought event and recent floods), and (ii) climate transition risks, which are financial risks that can result from the transition to a low-carbon economy, for example, due to changes in climate policy, technology, or market sentiment. The purpose of this report is to better understand the impact of these climate risks on Morocco's banking sector. This includes understanding the banking sector's exposure to sectors and regions that are vulnerable to climate physical and transition risks, as well as a quantification of climate impacts on banks' balance sheets under different scenarios. This report also takes stock of the Moroccan banking sector's current risk management practices and the supervisory response to climate-related financial risks.

Morocco's banking sector is exposed to climate physical risks, particularly floods and droughts. Natural catastrophes could affect property, corporate assets, household wealth, and firm profits, which could in turn reduce borrowers' ability to service their debt. For instance, crop producers and livestock farmers could face significant economic losses from droughts, a natural hazard to which Morocco is particularly vulnerable. This means that banks that are exposed to the agricultural sector could be directly affected by climate physical risks, while banks that are exposed to other sectors that are connected to the agricultural sector through the value chain (e.g., food processing and tourism) may also be adversely affected. In the case of severe drought events, other sectors may also be impacted, for example, when water scarcity and imposed water restrictions impact nonagricultural water users, too. Morocco is also highly vulnerable to floods, especially around the coastline, which is where most of the population and industrial activity is concentrated. Floods could affect the banking sector by reducing the value of assets and properties (e.g., mortgage loans). Floods could also disrupt key infrastructure such as road and communication networks. This could in turn generate economic losses in sectors such as transport, tourism, and agriculture and adversely impact banks that are exposed to these entities.

Moroccan banks' credit portfolios are geographically concentrated in a few regions, and some banks also exhibit a high sectorial concentration, with around a third of sectoral bank lending being exposed to particularly high physical risks. Casablanca, Rabat, and Marrakech jointly account for 77 percent of total credit exposure. Some banks have credit portfolios that are highly concentrated within a few sectors, such as agriculture. This has important implications on banks' climate risk profiles because some sectors are more likely than others to be impacted by climate-related disasters. For example, droughts can directly impact agriculture and the water sector, with indirect spillover effects on other sectors in the agricultural value chain, such as food processing. A significant share of bank lending is in areas that are prone to droughts, including in parts of the Marrakech-Safi Region and Souss-Massa Region that have historically had a high frequency of agricultural droughts. Floods can impact most sectors to some extent, if they have capital stock located in flood-affected areas. A large share of bank lending is in provinces that are vulnerable to pluvial or riverine flooding, including Rabat, Salé, and Marrakech. Considering both drought and flood risk, approximately a third of bank lending is to sectors that have particularly high physical climate risk (though other sectors are also likely to be impacted directly or indirectly by climate risks).

Catastrophe modeling suggests that climate change would amplify the economic damages caused by floods and droughts. This is seen across the spectrum of modeled return periods (RPs), with damages amplified for both frequent events and more extreme rare events. For example, the estimated direct damages and short-term indirect impacts for the "current climate" 1-in-500-year drought scenario over the three-year duration of the event are 41.8 billion Moroccan Dirham (MAD). These would significantly increase under climate change conditions, resulting in 58.6 billion MAD under the Representative Concentration Pathway (RCP) 4.5 for 2050 scenario (40 percent increase) and in 69.5 billion MAD under the RCP 8.5 for 2050 scenario (66 percent increase). On the other hand, catastrophe modeling suggests that for floods, the estimated direct damages and short-term indirect impacts for the "current climate" 1-in-500-year flood level scenario are 80 billion MAD for pluvial flooding. The direct impact of floods is projected to increase as a result of climate change. For pluvial flooding, the direct and short-term indirect impacts increase by approximately 8 percent to 86.7 billion MAD by 2050 under RCP 4.5 and approximately 30 percent to 104.8 billion MAD by 2050 under RCP 8.5. However, this modeling is based on projected changes in extreme precipitation at a country level, but some parts of Morocco may experience different increasing or decreasing trends in these extremes.

Macroeconomic and financial analysis suggests that climate change could exacerbate the impact of droughts on macroeconomic and financial indicators. Based on historical data, the model suggests that droughts with a 1-in-500-year RP could lead to lower production in agriculture, industry, and service sectors. This is expected to lead to various macroeconomic impacts, including annual Gross Domestic Product (GDP) losses up to 1.8 percentage points for a multiyear drought event. This could in turn increase the nonperforming loan (NPL) ratio and probability of default (PD) of the agriculture, industry, and service sectors. For instance, annual NPL ratios for the agriculture sector increases from 7.8 percent to up to 10.5 percent (mean NPL ratio of 8.9 percent for the 5 years of simulation). The capital adequacy ratio (CAR) could also reduce by 3.3 percentage points (mean reduction of 1.3 percentage points for the 5 years of the simulation). It is important to note that impacts could potentially be higher, as not all transmission pathways are captured in the modeling. While macroeconomic impacts on the financial sector may be less pronounced for events with a lower RP, such events can nonetheless have substantial impacts on individual firms and affect livelihoods and poverty levels. The analysis suggests that climate change could exacerbate the impact of droughts on macroeconomic and financial sector indicators. Notably, the impact on financial variables could almost double in the most extreme scenario (RCP 8.5 for 2050) compared to the 1-in-500-year drought scenario under historical climate conditions. Under this scenario, the GDP losses are estimated at 3.5 percentage points, and the mean reduction in CAR for the 5 years of the simulation is estimated at 2.2 percentage points.

Macroanalysis similarly suggests that climate change could exacerbate the impact of floods on macroeconomic and financial indicators, although the impact is significantly lower compared to the drought scenarios. Based on historical data, the model suggests that extreme cases of pluvial flooding could lower outputs in the agriculture, industry, and service sectors. This could lead to various negative macroeconomic impacts, including annual GDP losses up to 1.6 percent for the 1-in-500-year level of pluvial flooding under historical climate conditions. Floods are relatively short-duration events, unlike droughts, which have a longer-lasting direct impact. The model therefore estimates that the overall impact of flooding on financial risk metrics is significantly lower relative to drought. Nevertheless, the model still shows that floods could have a negative impact on financial risk metrics. For instance, the annual NPL ratio increases by up to 0.7 percentage points for the most severely affected sector (agriculture) (mean increase of 0.3 percentage points for the 5 years of simulation), while annual CAR loss remains limited to a maximum of 0.2 percent (mean reduction of 0.11 percentage points for the 5 years of the simulation). Furthermore, the analysis suggests that climate change could significantly worsen floods' impacts on macroeconomic metrics, though the impacts on financial risk metrics remain relatively small (e.g., for the 1-in-500-year flood level under RCP 8.5 in 2050, the mean reduction in CAR for the 5 years of the simulation is 0.14 percentage points).

A complementary microanalysis suggests that the financial impact of droughts and floods varies substantially across banks. The impact differs widely across institutions, with banks with larger agriculture and household loan portfolios expected to be more affected by droughts. The analysis also suggests that underlying drivers behind the increase in NPLs vary among banks. For the larger banks in Morocco, the overall increase in NPLs is primarily coming from the deterioration in the large household loan portfolio rather than the small agriculture loan portfolio. On the other hand, the vulnerability assessment suggests that flood impacts are concentrated geographically.

The impact of climate transition risks on the banking sector is estimated to be substantial but potentially manageable. The impact of climate transition risks on the banking sector may be manageable since Morocco is a small greenhouse gas (GHG) emitter, representing only 0.16 percent of global carbon dioxide (CO_2) emissions. Nonetheless, national GHG emissions are on the rise (particularly from the energy sector), which could increase exposure to climate transition risks in the future. Based on industries' GHG emissions and GHG emission intensity, industries that are potentially sensitive to transition risks in Morocco could include electricity generation, transport, mining, agriculture, manufacturing, and utilities. Since the European Union (EU) is Morocco's largest trading partner, "transition-sensitive" industries may also include those affected by the EU's Carbon Border Adjustment Mechanism (CBAM), such as industries associated with the production of cement, electricity, and aluminum.

The report found that overall credit exposure to industries defined as highly or moderately transition-sensitive accounts for 24.3 percent of total loans and 43.6 percent of loans to nonfinancial corporates (NFC). Exposures are highest to the manufacturing sector (9 percent of total loans), electricity (5 percent of total loans), and agriculture (4 percent of total loans). While most banks have an exposure of less than 25 percent to transition-sensitive industries, four banks have exposure that exceeds 50 percent. The analysis suggests that exposure to transition risks is concentrated in small and medium-sized banks that have specialized credit portfolios.

To estimate future impacts of transition risks, a vulnerability assessment was conducted based on two carbon price scenarios. The model found that systemwide, 1.9 percent of total corporate loans—0.7 percent of banking sector assets—are estimated to be at increased credit risk,[1] following the implementation of a \$25/tCO_2 carbon tax. A \$75/tCO_2 carbon tax would put 8.4 percent of systemwide corporate loans—3.1 percent of banking sector assets—at increased credit risk. The results vary substantially across banks, reflecting banks' different sectoral lending focuses, the share of NFC lending in total lending, and the share of lending to total assets. Most of the outliers in terms of either very high or very low increases in credit risk are small banks with specialized portfolios.

The report's quantitative findings should be interpreted with caution, given the uncertainties and complexities of estimating climate-related financial risks. Climate impacts on the banking sector could be underestimated due to the inherent uncertainties in modeling climate tipping points. There are also complex interlinkages between macroeconomic, financial, and climate impacts (e.g., interaction between transition and physical risks or interaction between climate change and other crises such as the pandemic), which could amplify shocks to the financial system. Furthermore, the lack of granular and timely data (e.g., data on financial exposure and GHG emission intensity), and the diversity of modeling approaches could reduce the robustness and accuracy of the assessment. The assessment is therefore intended to be explorative in nature and should be updated over time as the understanding of climate risks improves.

Moroccan banks are advancing on the integration of climate risks in risk management frameworks, although more work will be needed to properly embed this in their activities. Based on a survey conducted within the banking sector (in July 2021), the report found that while awareness of climate risks among banks is high, most banks are still in early stages of integrating climate into their risk management frameworks and have not conducted climate risk vulnerability assessments. Since then, progress has been made with several banks considering climate risk in their Internal Capital Adequacy and Assessment Process (ICAAP). Some banks, particularly those that are multinational, have taken steps to integrate climate into their governance framework, for example, by ensuring that there is board involvement on climate issues. A limited number of banks are disclosing information on climate risks, but around half of the banks are planning to enhance disclosure based on the Task Force on Climate-Related Financial Disclosures (TCFD). In general, banks

1 Estimates for the increase in credit risk are obtained by multiplying the increase in debt-at-risk at the sectoral level with each bank's lending exposure to these sectors.

are calling for more guidance, data, and capacity building from authorities and international organizations to help assess and manage climate risks.

The Bank Al-Maghrib (BAM) has identified climate risk management as a key priority. BAM issued the directive on the management of climate and environmental financial risks in 2019, which gives high-level guidance to banks. Moving forward, BAM intends to develop more detailed supervisory guidance in response to climate risks, particularly around stress testing and reporting. BAM is also working on integrating climate risks into day-to-day supervisory tools and practices, such as their assessment in the BAM's Supervisory Review and Evaluation Process (SREP), in line with its directive on climate and environmental risks and other relevant standards, and the integration of climate risks in ICAAP reports. Over time, BAM may consider further integration of these risks into the ICAAP and the fit and proper testing framework. BAM will also identify potential regulatory actions that are required to address critical data gaps around climate risks, including actions that may involve policymakers beyond BAM, such as disclosure and reporting requirements for corporates and a green taxonomy. Based on this report's initial climate risk analysis, BAM is assessing whether the central bank's macro- and microprudential monitoring and assessment framework needs to be updated to structurally embed the identified climate risks. Going forward, particular consideration will be given to the Basel Committee on Banking Supervision's (BCBS's) Principles on the effective management and supervision of climate-related financial risks to ensure alignment with global standards.

Based on this report's findings, a range of policy recommendations has been identified to further assess and manage climate-related financial risks for the banking sector. Table ES1 identifies a set of policy options, the authorities that may be responsible for their implementation, and the tentative timeframe for developing the policies. Section 5 includes further context on the preliminary suggestions on policies and actions that could be taken to enhance the management of climate-related risks and enhance financial protection against climate and disaster risks.

TABLE ES1
Policy recommendations for assessing and managing climate risks for the banking sector

POLICY RECOMMENDATION	RELEVANT AUTHORITIES	TIMEFRAME
• Continue to improve the understanding and management of climate-related financial risks by updating the risk analysis as needed, collecting data and setting indicators required to monitor key climate risks, and continuing to build institutional capacity.	BAM	SHORT-TERM
• Develop a plan to further integrate climate risk analysis into the central bank's macro- and microprudential monitoring and assessment framework.	BAM	MEDIUM-TERM
• Develop more detailed supervisory guidance for the banking sector to enhance the management of climate risks, building on Directive 5/W/2021.	BAM	SHORT-TERM
• Consider thematic supervisory review on climate or on-site supervision for highly exposed entities.	BAM	MEDIUM-TERM
• Address data gaps that limit authorities' and financial institutions' ability to assess and measure climate-related financial risks.	Line Ministries (e.g., the Ministry of Finance, Ministry of Energy), BAM	SHORT-TERM
• Collaborate with relevant ministries and authorities to provide forward-looking climate guidance to inform long-term decision-making and risk management practices.	Line Ministries, BAM	SHORT-TERM
• Stimulate the development of private insurance markets and/or public schemes to transfer climate and disaster risks (including to global reinsurers).	BAM, Ministry of Finance, Ministry of Environment	SHORT-TERM

*Note: ST = short term (1–3 years); MT = medium term (3–5 years)

SECTION 1

Introduction

A growing number of central banks and regulators have issued warnings that climate risks could fundamentally affect their core mandate of maintaining financial stability. The impact of climate change on the financial sector can be broadly categorized into two types of risks: (i) climate physical risks, which are financial risks stemming from the gradual and abrupt impacts of climate change, and (ii) climate transition risks, which are financial risks that can result from the process of a low-carbon transition prompted, for example, by unanticipated changes in climate policy, technology, or market sentiment.

The precise impact of climate change on the financial sector is not well understood by financial institutions and central banks. Whether climate change impacts would be idiosyncratic, being limited to certain regions and assets, or lead to "green swan"[2] events, potentially triggering a financial crisis, depends on the climatic, socioeconomic, and financial conditions. In addition, there are complex interactions between climate change and other types of risks (e.g., pandemic, cyberattacks, political meltdowns), which could create compounding impacts between climate risks and other crises, generating nonlinear effects that can amplify economic and financial losses. Most backward-looking risk assessments and models are not suited to properly assess climate risks. This is because these models fail to assess the nonlinearity and deep uncertainty of future climate scenarios and distributions and do not fully capture (direct and indirect) risk transmission channels to the economy and financial markets.

A climate risk vulnerability analysis can be an important tool to address these challenges, as it can shed light on the potential impact of severe but plausible climate scenarios that may occur but for which no historical precedent is available. Vulnerability assessments are used to evaluate the potential impacts of climate change on the stability of the financial system and the soundness of the banking sector. These analyses are typically explorative in nature and have so far not been used as pass/fail exercises to increase capital requirements for financial institutions (unlike traditional stress testing). The Network of Central Banks and Supervisors for Greening the Financial System (NGFS) published a Scenarios in Action report[3] in 2021 that described progress made by NGFS members to develop climate-scenario exercises. The report shows that four members—all in Europe—have concluded a climate risk vulnerability assessment, and 26 members are working on, or are planning, an exercise, including various emerging markets and developing economies (EMDEs).

2 See BIS (2021), "Green Swans: central banking and financial stability in the age of climate change"
3 NGFS (2021), "Scenarios in action: a progress report on global supervisory and central bank climate scenario exercises"

Objective and approach

The purpose of this report is to conduct a climate risk assessment for Morocco's banking sector. In particular, the report aims to do the following:

- **Assess the impact of climate physical and transition risks on the banking sector:** This is achieved by (i) identifying the key transmission channels through which climate physical and transition impacts translate into risks for Morocco's banking sector, (ii) evaluating the banking sector's exposure to regions and sectors that are vulnerable to transition and physical risks, (iii) developing suitable physical and transition risk scenarios that are most relevant to Morocco's banking sector and that reflect recent trends and patterns associated with climate change and climate policy, (iv) running catastrophe risk modeling to estimate the direct damages and short-term indirect impacts associated with extreme events, and (v) conducting vulnerability assessments to gauge the future impact of climate physical and transition risks on banks' portfolios.

- **Evaluate the banking sector's response to climate risks:** This includes taking stock of (i) regulatory and supervisory responses to climate risks as well as (ii) banks' current climate risk management practices.

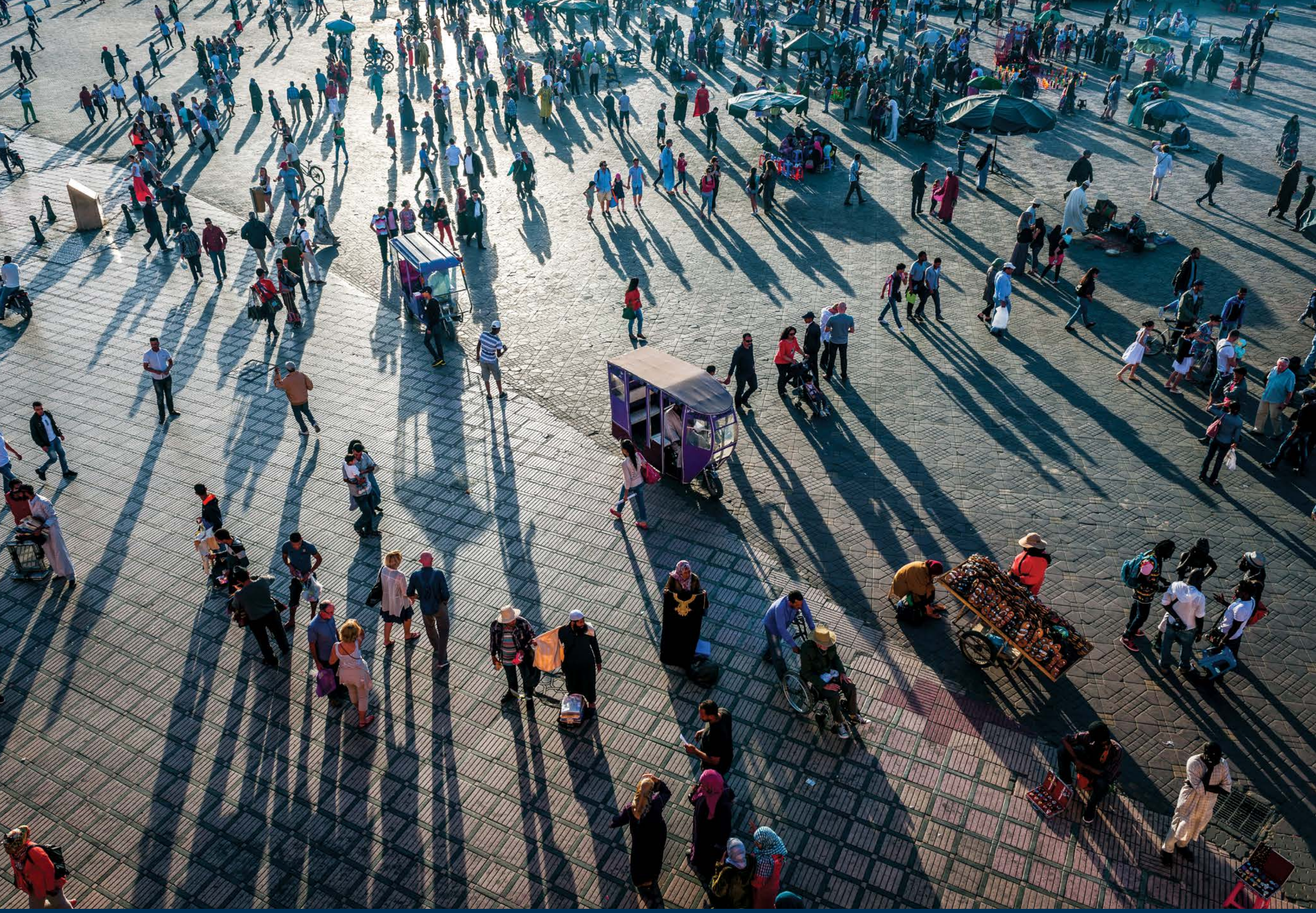
- **Identify policy actions:** Based on the analysis, this report identifies key policy priorities and next steps to further assess and manage climate risks for the banking sector.

This report is written at a time when Morocco is in the midst of a climate-related disaster, highlighting the urgent need for improved assessment and management of climate risks. The current drought event has resulted in exceptionally low cereal production, with production dropping 67 percent compared to last year.[4] This, combined with global supply chain disruptions associated with the war in Ukraine, has resulted in high domestic food price inflation[5] and wide-reaching economic impacts.[6]

This work is particularly innovative as it represents the first comprehensive analysis of physical and transition climate-related risks in Africa and is one of only a handful in emerging markets and developing economies globally. Furthermore, it is the first such analysis to attempt to quantify the financial sector impacts of drought risk under climate change. The analysis of drought considers impacts on crop production, cereal imports, and impacts on agricultural populations (including job losses), as well as wider indirect impacts on the economy and financial sector. While the analysis focuses primarily on drought impacts via the agricultural sector (and associated transmission channels), the approach could be extended in the future to consider other nonagriculture-related sectors.

This work is particularly innovative as it represents the first comprehensive analysis of physical and transition climate-related risks in Africa and is one of only a handful in emerging markets and developing economies globally.

4 Kingdom of Morocco (2022), Cereal Campaign 2021/2022: Production of 34 Mln Quintals.
5 World Bank (2022), Food Security Update September 2022.
6 Diaz Cassou, J., Iraqi, A., Megevand, C., Marzo, F. (2022), Morocco Economic Update: The Recovery is Running Dry. Washington, D.C.: World Bank Group.



SECTION 2

Context

2.1 **Financial sector context**

Morocco's financial sector is large and dominated by banks. Total financial sector assets stood at 244 percent of the GDP in 2020. The largest subsector is *établissements de crédit*, which accounts for 62 percent of total financial sector assets or roughly 138 percent of the GDP. The credit sector is dominated by 19 banks, while other credit institutions, including consumer credit companies, leasing companies, mortgage companies, factoring companies, and microfinance entities, are very small in terms of assets. The second largest subsector is collective investment schemes (21 percent of total financial sector assets), followed by insurance companies (9 percent of total assets). The banking sector will be the focus of this report's analysis, considering the size and importance of the banking sector.

The banking sector exhibits a sizeable presence of foreign institutions and state-owned banks. The 19 banks operating in Morocco can be split into three subgroups based on their ownership structure. The largest group in terms of assets consists of domestic private banks—seven banks that account for almost two-thirds of banking sector assets. The second subgroup consists of five state-owned banks, accounting for around 19 percent of total assets. The third subgroup consists of seven banks, which are majority foreign-owned. These banks account for around 16 percent of banking sector assets. The banking sector is concentrated, and the three largest banks,[7] all of which are domestic private banks, account for 63 percent of total banking sector assets.

Several Moroccan banks have cross-border operations, especially in Sub-Saharan Africa. The largest Moroccan banks—Attijariwafa Bank, Groupe Banque Centrale Populaire, and Bank of Africa—have a strong presence through subsidiaries in North Africa[8] and Sub-Saharan Africa.[9] Overall, these three banks have 51 subsidiaries and 22 branches in 35 countries, including 27 in Africa, seven in Europe, and one in Asia, as of December 2021.

Banks follow a traditional business model based on lending and a high reliance on deposit funding. The asset side of banks' balance sheets is dominated by credit, which accounts for almost 60 percent of systemwide bank assets. Credit is roughly equally split between consumer credit (18 percent of bank assets), working capital credit (14 percent of bank assets), and mortgages (18 percent of bank assets). However, banks also hold sizeable investments in trading and investment securities, accounting for 19 percent of their assets. Almost two-thirds of the banks' security holdings consist of government securities. Four percent of banks' assets take the form of direct equity holdings of related companies. The liability side of banks' balance sheets consists of 67 percent of deposits, out of which roughly two-thirds are current accounts. Banks rely relatively little on wholesale funding and debt securities, which are only 5 percent of total liabilities. Dollarization is low, and deposits and loans are overwhelmingly denominated in local currency.[10]

Financial soundness indicators point to a relatively well-capitalized banking sector but indicate high levels of NPLs. The systemwide CAR stood at 16 percent of risk-weighted assets (RWA) in mid-2021 and changed little throughout the COVID-19 pandemic.[11] Profitability is moderate with the systemwide return on equity (ROE) and return on assets (ROA) standing at 12.2 percent and 1.2 percent, respectively. Prepandemic profitability was sustained, despite slow credit growth. Systemwide NPLs increased to 8.3 percent in June 2021 from 7.5 percent in December 2019. However, the banking sector has consolidated its financial base through an increase of performance and a reinforcement of its equity.

7 BAM classifies these three banks (Attijariwafa Bank, Groupe Banque Centrale Populaire, and Bank of Africa) as systemically important banks (D-SIBs).
8 In particular, Tunisia and Egypt.
9 Primarily West African countries, such as Senegal, Côte d'Ivoire, Mali, Burkina Faso, Togo, or Niger.
10 BAM data as of June 2021. https://www.bkam.ma/Supervision-bancaire/Structure-du-systeme-bancaire/Etablissements-de-credit/Indicateurs-financiers-et-statistiques/Bilan-des-banques
11 The analysis in the remainder of this report uses end-2019 for the vulnerability analysis to avoid biases arising from the impact of the pandemic and related support measures. The analysis was performed considering a five-year time span (from 2020 to 2024).

2.2 **Climate adaptation and resilience**

2.2.1 **Physical climate change trends**

Morocco is highly vulnerable to climate change and climate shocks. It is recognized as vulnerable to climate change impacts by the Notre Dame Global Adaptation Initiative (ND-GAIN) Index,[12] the Climate Risk Index,[13] and the Inform Risk Index,[14] with high risk levels for several categories of natural hazards (Table 1). Overall, impacts from natural hazards are estimated to cost the country $575 million annually.[15] This section analyzes three climate physical impacts that are highly relevant for Morocco, namely (a) droughts and water scarcity, (b) floods, and (c) sea level rise. However, it is important to note that Morocco may also be vulnerable to other risks, such as increases in average temperatures and increases in the frequency and severity of heat waves, which may have wide-ranging impacts, including reduced labor productivity and increased energy demand (e.g., for air conditioning). While a detailed analysis of these risks is outside the scope of this report, they present an important area for future analysis. Future analyses could also consider compound scenarios, such as drought combined with an international food price shock, as is currently being experienced in Morocco.[16]

TABLE 1
Physical risk profile for Morocco

Hazard	Risk level	Comments
SLR / Coastal flood	HIGH	Potentially damaging waves are expected to flood the coast at least once in the next 10 years.
River flood	HIGH	Potentially damaging and life-threatening river floods are expected to occur at least once in the next 10 years.
Urban flood	MEDIUM	There is a chance of more than 20 percent that potentially damaging and life-threatening urban floods occur in the coming 10 years.
Heat wave	HIGH	Prolonged exposure to extreme heat, resulting in heat stress, is expected to occur at least once in the next five years.
Drought / Water scarcity	MEDIUM[17]	There is up to a 20 percent chance droughts will occur in the coming 10 years.
Wildfire	HIGH	There is a greater than 50 percent chance of encountering weather that could support a significant wildfire that is likely to result in both life and property loss in any given year.

Source: ThinkHazard!

12 The ND-GAIN Country Index summarizes a country's vulnerability to climate change in combination with its readiness to improve resilience. Countries are ranked from 1 (lower risk) to 181 (lower risk). Morocco ranks 70th.
13 The 2019 Climate Risk Index (CRI) score is based on the impacts of extreme weather events and its associated socioeconomic data. Countries are ranked from 1 (higher risk) to 182 (lower risk). Morocco ranks 90th with a score of 79.67.
14 The INFORM Risk Index is a global risk assessment tool that uses three dimensions: hazard and exposure, vulnerability, and need for coping capacity. Countries are ranked from 1 (higher risk) to 191 (lower risk). Morocco ranks 91st.
15 World Bank (2022), Morocco Country Climate and Development Report.
16 World Bank (2022), Food Security Update September 2022.
17 Based on ThinkHazards! methodology, frequency and intensity of water scarcity events rank as medium. However, based on the author's own analysis, this report considers Morocco's vulnerability to agricultural and hydrological drought to be high, as the agricultural sector is mostly relying on rain-fed crops.

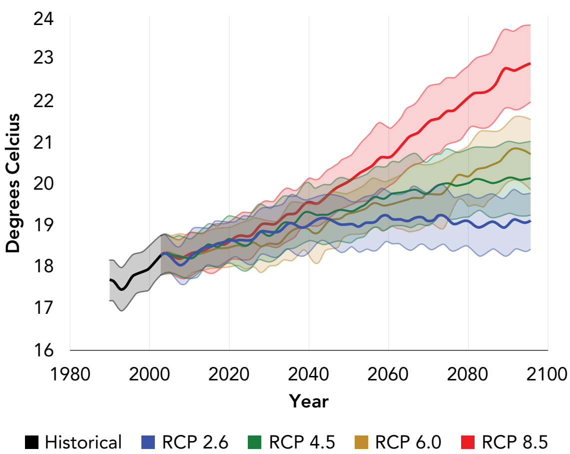
Droughts and water scarcity

Morocco is one of the most water-stressed countries in the world. With an average temperature increase above global warming trends and an overall decrease in precipitations (with more erratic patterns), Morocco has witnessed an accelerated depletion of water resources in recent decades. Furthermore, renewable groundwater resources are overexploited. Groundwater now accounts for about 35 percent of all water used in agriculture. However, as the frequency and severity of droughts increase, groundwater usage can significantly increase. The challenge of water scarcity is compounded with the deterioration of water quality. Only 54 percent of the population[18] is connected to wastewater treatment plants and less than half of the wastewater collected is treated[19] before being released into oceans, rivers, and soil. Most industrial sewage is untreated before being disposed of directly into the environment. The agriculture sector contributes significant amounts of pollution to water sources through uncontrolled use of pesticides and fertilizers.[20]

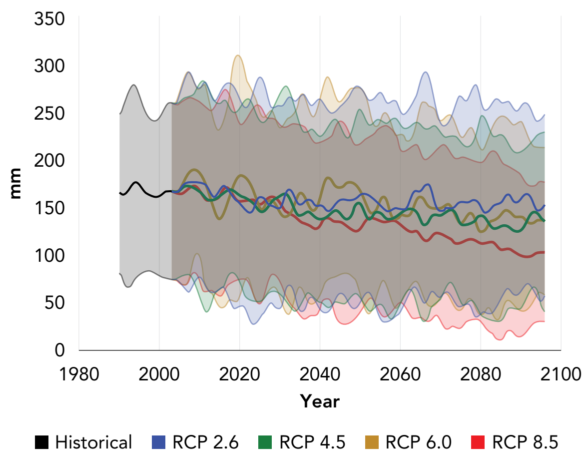
FIGURE 1

Projected average temperature, average precipitation, and very hot days (TMax >35°C) for Morocco from 1986 to 2099

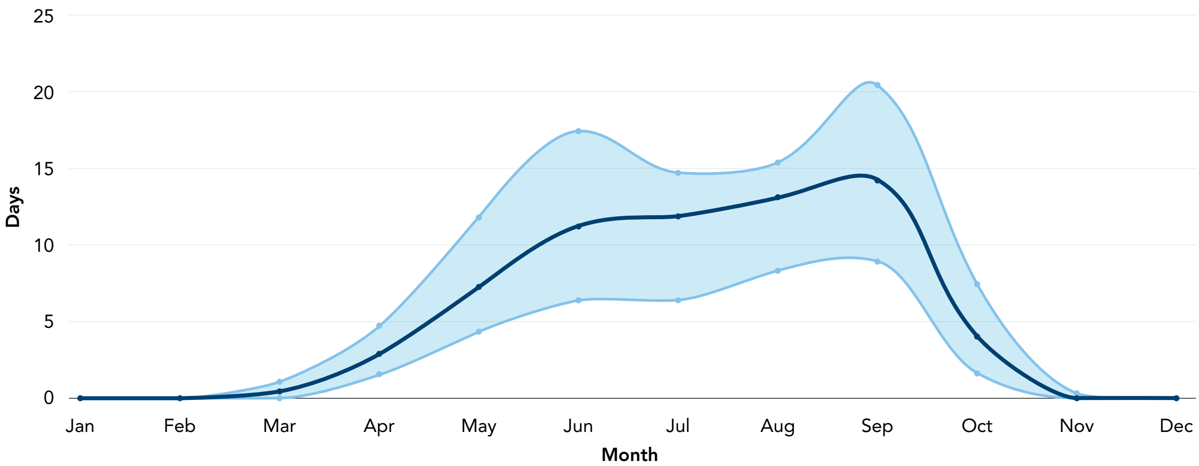
Projected average temperature



Projected average precipitation



Projected very hot days (TMax >35°C)



Source: World Bank Group's Climate Change Knowledge Portal

18 This represents about 20 million Moroccans in urban and peri-urban centers.
19 Wastewater treatment capacity grew from 50,000 m³/day in 2000 to 900,000 m³/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.
20 Estimated at 1,200 tons of nitrogen and 500 tons of pesticides per year.

Morocco is currently facing its worst drought period in three decades, with rainfall around 65 percent below the annual average, further emptying reservoirs that were already reduced after years of less predictable weather. The climate in Morocco is already warming and precipitation is declining. Since the beginning of the 20th century, Morocco's average annual temperature has increased by 1.5°C, and since the 1960s, the number of hot days per year has more than doubled.[21] This trend has been accelerating over the last 30 years, with a 0.42°C increase per decade observed since the 1990s, greatly exceeding the global average (0.28°C per decade). As a result, Morocco has been experiencing more frequent droughts over the past two decades, rising from one event every 10 years at the beginning of the last century to five to six per decade at the start of the present one. Past official drought declarations, triggering government emergency relief, were made in 1992–1995, 1998–2001, 2005, 2007, and 2015–2016.

Climate change will likely increase the frequency and severity of droughts in Morocco over time. Mean temperatures in North Africa are projected to increase by up to 2.6°C by 2050 relative to 1994–2005.[22] North Africa is also expected to see increased water scarcity and reduced soil moisture. Mean annual precipitation is projected to decrease in North Africa. Droughts are projected to increase in frequency, and duration is projected to double above 2°C global warming.[23]

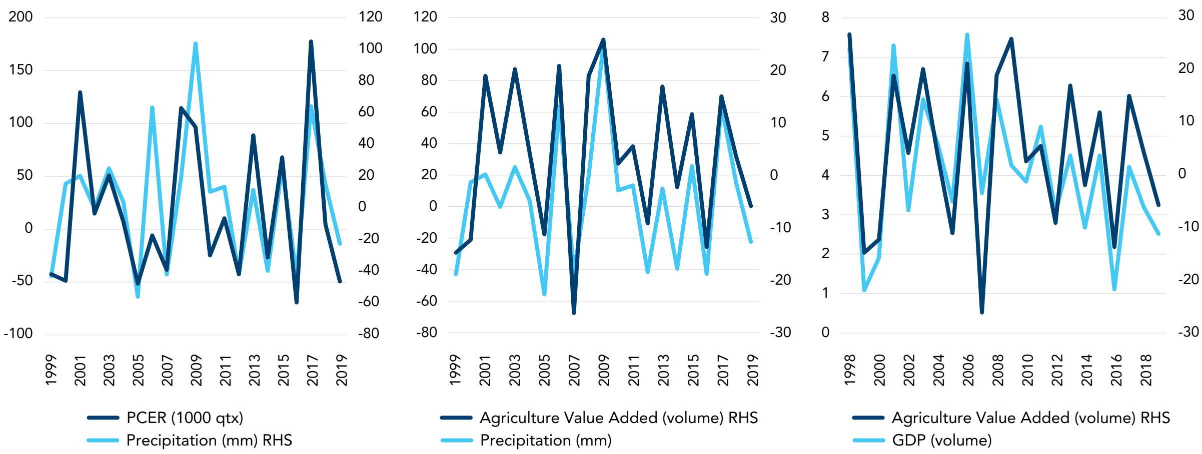
The impact of droughts is particularly severe for the agriculture sector. Agriculture in Morocco is dominated by small subsistence farms that are in areas with limited soil and water resources. The main cultivated crops in Morocco are also the most vulnerable to climatic risk. For example, cereals (59 percent of land use), legumes (6 percent), and market gardening (3 percent) are highly dependent on precipitation and temperature.[24,25] Increased heat is projected to amplify stress on crops and impact the productivity and length of the growing season. Analyses suggest that the growing season for crops is expected to decrease by one to three months by the end of the century.[26,27] Decreased water availability and the reduction in soil moisture may alter suitable areas for agriculture or the production of specific crops. Crop yields are expected to drop over the years, with cereals, legumes, and citrus being particularly affected. Livestock farming is also likely to decrease due to the combined effect of depletion of livestock feed (cereals) and reduction of rangelands caused by desertification.[28]

Morocco has been experiencing more frequent droughts over the past two decades, rising from one event every 10 years at the beginning of the last century to five to six per decade at the start of the present one.

The impact of drought on the economy is significant. The agriculture sector (including livestock) is a critical component of Morocco's economy, accounting for approximately 12 percent of Morocco's GDP, 38 percent of its total employment, and 74 percent of employment in rural areas.[29] Considering the high proportion of nonirrigated farms, fluctuations in rainfall levels significantly impact agriculture productivity and value added, which contribute to Morocco´s GDP growth volatility (Figure 2).

21 Direction des Etudes et des Prévisions Financières (2020).
22 IPCC (2022), Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.). Cambridge: Cambridge University Press.
23 Ibid.
24 Modeling System for Agricultural Impacts of Climate Change (MOSAICC) website.
25 The growing season, which today runs from November to April, will narrow to November to March in 2050 and January to March by 2090 (INRA 2017).
26 INRA (2017).
27 Under an optimistic scenario (RCP 4.5), overall national-level production of wheat and barley may be little changed by midcentury (2040–2069) but there can be major differences between regions particularly for barley. Consequently, impacts on imports and household consumption may be small. Barley prices could increase by up to 111 percent, but wheat and others are less affected. GDP impact is minor. Some modeling suggests that regions such as the northern and mountainous areas could become more favorable for wheat. The plains of the Fes-Meknes region are more heavily affected. Yields could be more volatile, increasing risks for producers. Under a more pessimistic scenario (RCP 8.5), some analyses suggest that wheat and barley production could decline in all regions. Prices of imports will rise, and household consumption will be negatively affected (INRA 2017 based on MOSAICC).
28 Balaghi et al. (2010).
29 Direction des Etudes et des Prévisions Financières (2020), Le Maroc à l'épreuve du changement climatique: situation, impacts et politiques de réponse dans les secteurs de l'eau et de l'agriculture. Policy Brief no. 18.

FIGURE 2
Historical impacts of droughts on the economy – Droughts and GDP fluctuation



Source: World Bank

Floods

Morocco is highly vulnerable to floods due to its geographical position, high rainfall variability, and topography. Morocco suffers from different types of floods (mainly riverine and pluvial) that are not uniformly distributed across Morocco's provinces. These floods can occur in coastal, rural, or urban areas and are subject to different severity levels. With the increased urbanization growth rates and the development of infrastructures in these areas, floodwaters have become a source of exacerbated risk to infrastructure, economic activity, and populations. When floods occur, they wreak havoc on properties and have dramatic impacts on populations and livelihoods. Large urban centers located in the northeastern plains of the country, such as Tangiers and Casablanca, are more exposed to flooding events. In arid and semi-arid regions of Morocco, flash floods can fill dry stream beds very rapidly, often taking a heavy toll in terms of human lives. In the mountainous areas near the coast, episodes of intense rainfall cause high surface runoff, which generates floods that can quickly reach high-peak flow.

The impact of both direct and indirect damages from floods can be very severe. Direct damages are those that occur due to the physical contact of flood water (e.g., damage to private buildings and contents, destruction of infrastructure such as roads and railroads, erosion of agricultural soil, destruction of harvest, and damage to livestock). Indirect damages are induced by the direct impacts and occur—in space or time—outside the flood event (e.g., disruption of public services, business interruption, induced production losses to companies outside the flooded area, cost of traffic disruption, loss of tax revenue). From 1900 to 2020, floods resulted in almost 3 billion MAD in damages in Morocco.[30]

Sea-level rise

Morocco has an extensive coastline, on which 60 percent of the population, 90 percent of industrial activity, and significant natural reserves are located. Many locations along the coasts are physically and socioeconomically vulnerable to accelerated sea-level rise, mainly due to their low topography and high economic and ecological values. The problem is exacerbated by a rapidly growing population in urban coastal zones, where people continue to migrate from the drought-ridden interior, with an estimated sixfold increase

30 World Bank Group (2021), Climate Risk Profile: Morocco.

in 2025 compared to 1985 levels. Additionally, tourism and other industries along the coast continue to be a development priority for the country, putting the coast, which is vulnerable to sea-level rise, under pressure from housing and development, as well as tourism.

Sea-level rise is a slow and long-lasting event that contributes to more damaging flood events, coastal inundations, salinization of coastal aquifers, and water shortages. Even a slight increase in sea level can have devastating effects on the coastal area. The major physical impacts of a rise in sea level include erosion of beaches[31] and land loss, destruction and damage to infrastructure and productive capital, and disruption of human activities and services. Sea-level rise can also lead to saltwater intrusion, increased salinity of agricultural land, and damage to fish processing plants, which may significantly deteriorate the productivity of the agricultural and fishing sectors.

2.2.2 **Climate adaptation and resilience policies**

Morocco submitted its updated nationally determined contribution (NDC) to the United Nations Framework Convention on Climate Change (UNFCCC) in 2021. Key priorities highlighted in the updated NDC focus on the country's water resources, agriculture and forestry, energy, and health sectors. The objectives defined in the NDC were built on the 2020–2030 National Adaptation Plan (NAP), which sets a roadmap to support adaptation planning and priority actions. The NAP describes the governance framework, including the role of subnational actors and civil society in supporting Morocco's plans for climate adaptation and resilience. It also includes scientific research on physical risks and ways in which Morocco could prevent and reduce physical risks.

In 2021, the government adopted the National Disaster Risk Management (DRM) Strategy (2020–2030). The strategy builds on the extensive work on the DRM spearheaded by the Ministry of Interior over the past decade. It is centered around five strategic axes and represents a major milestone for providing a more comprehensive approach to managing disaster and climate-related risks, with a focus on promoting ex-ante risk reduction and preparedness to complement ex-post recovery activities. It also puts in place a strengthened (horizontal and vertical) coordination framework among the multiple institutions with responsibilities on the DRM agenda.

The government has also developed a strong disaster risk finance and insurance program. Since 2008, the government has been working with The World Bank on hedging disaster and climate-related risks, including through market-based solutions. While financing mechanisms for disaster recovery in Morocco have historically been based on an ad hoc and ex-post basis, the government recently developed an ambitious disaster risk financing agenda, which led to the development of a national catastrophe risk insurance program and the adoption of Law No. 110-14 in 2016. The law sets up a dual mechanism with (i) a private insurance scheme for the insured and (ii) a basic compensation system for the uninsured, through the Fonds de Solidarité contre les Evènements Catastrophiques. The government has also initiated several projects to improve its understanding of natural and catastrophic risks through advanced modeling of climate risks (specifically drought and flood). The government aims also to address a broader range of perils beyond the scope of Law 110-14, including climate change and other complex risks and their compound effects, which are currently not modeled in Morocco. This is expected to directly feed into the National Disaster Risk Finance strategy and will make use of the latest risk information and technology to produce advanced risk models and near real-time risk information.

31 Approximately two-thirds of Morocco's beaches are at risk of coastal erosion from sea-level rise. This has already become a critical issue in Saidia (due to its low altitude and sandy beaches) and Tangier, where erosion is already estimated to be 2–3 meters per year. Additional low-lying coastal lands at risk from flooding due to sea-level rise include the Nador Lagoon, the Moulouya River and its delta (a biologically important estuary), and the low-lying coastal plains of Oued Nekkor and Oued Laou. If sea levels rise 0.86 meters by 2100, Tangier Bay is projected to lose 99.9% of its port infrastructure and 63% of the city's industrial zone.

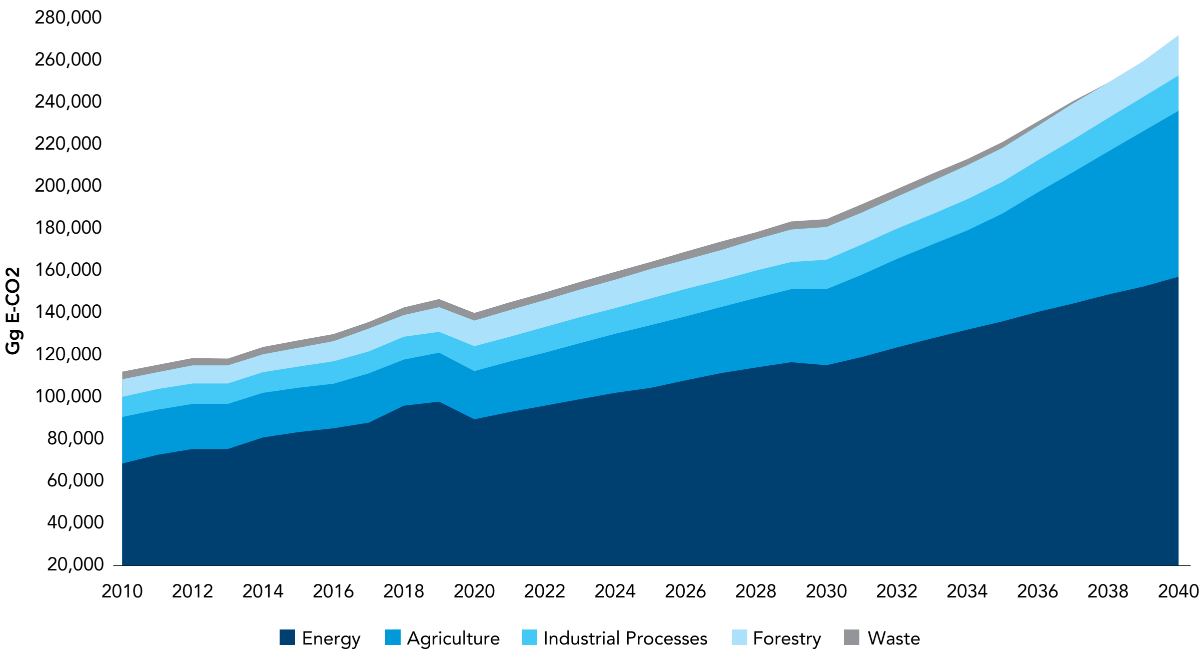
2.3 **Climate mitigation**

2.3.1 **GHG emission trends**

While Morocco is a small greenhouse gas (GHG) emitter, GHG emissions have been on the rise in recent years. Morocco only represents around 0.16 percent of global CO_2 emissions. However, national GHG emissions have almost doubled between 2000 and 2018 and could continue to increase as the economy grows. Nevertheless, while Morocco's economic growth and CO_2 emissions have historically been closely related, emissions have recently grown at a slower rate than the economy, which suggests that the carbon intensity of the GDP is declining.

The energy sector is by far the largest contributor of Morocco's emissions. According to Morocco's national communication, energy (transformation and final use) represents 65.1 percent of total GHG emissions. The second largest contributor is agriculture (22.1 percent), followed by industrial processes (6 percent), and waste (5.4 percent).[32] Morocco's energy consumption continues to be dominated by imported fossil fuels, particularly oil and coal (Figure 4). In 2019, oil contributed to 56.5 percent of the total energy supply, followed by coal (29.8 percent) and natural gas (3.9 percent). Morocco's reliance on imported fossil fuels has macroeconomic implications, since this increases the country's trade deficit and increases the country's vulnerability to the large fluctuations of global hydrocarbon prices. Despite minimal coal reserves, Morocco has accelerated the use of coal and has commissioned three coal power plants to expand its coal-fired power generation. Natural gas is also projected to reach 23 percent of total electricity-installed capacity by 2030 in Morocco.[33]

FIGURE 3
Expected baseline emissions (2010–2040)

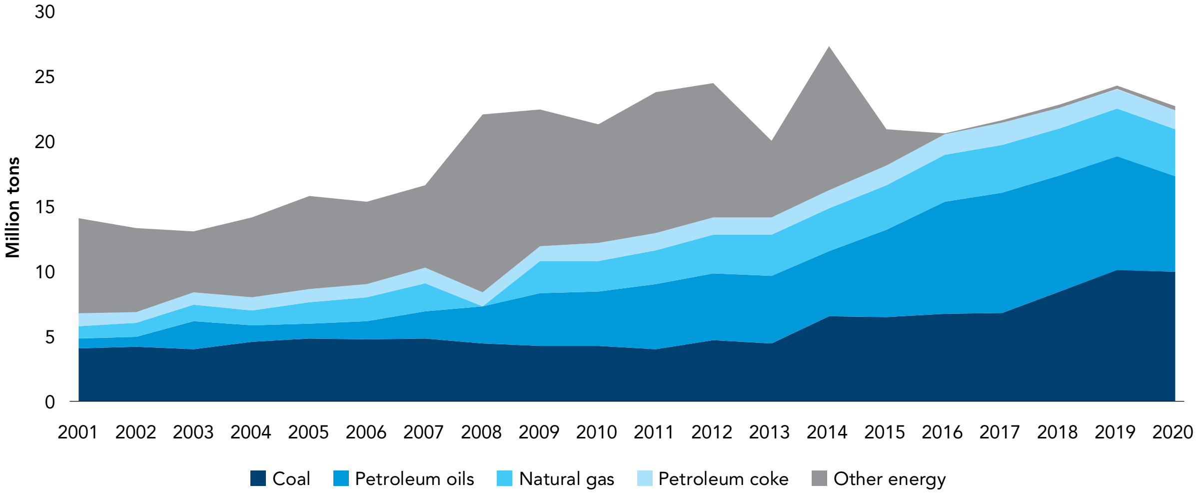


Source: Government of Morocco, 2016, National Communication of Morocco to UNFCCC

32 Government of Morocco (2018), "National Communication"
33 Climate Action Tracker,"Morocco"

FIGURE 4

Morocco's fossil fuel imports (million tons)[34]



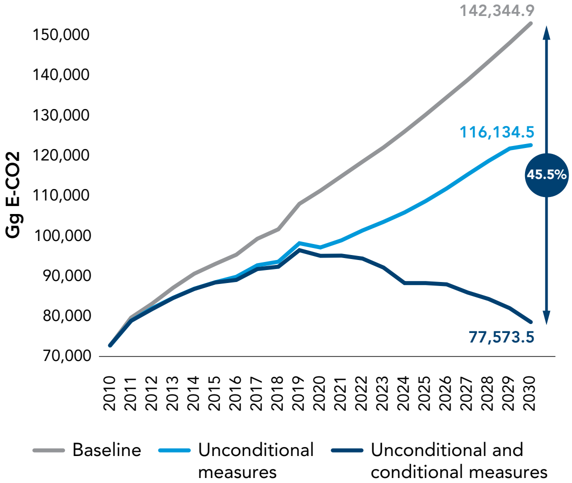
Source: Trademap.org; IEA; World Bank Commodity Price Data

2.3.2 Climate mitigation policies

Despite being a small GHG emitter, Morocco has set ambitious decarbonization goals under its updated NDC and long-term strategy. Morocco's revised NDC has set a target to reduce 45.5 percent of its GHG emissions by 2030 relative to a business-as-usual (BAU) scenario (Figure 5). As shown in Figure 6, the updated NDC sets targets for all seven sectors, with a detailed list of measures put forward for both its conditional and unconditional target. In 2021, the government also published its long-term strategy, demonstrating its ambition to contribute toward the Paris Agreement's overall objective of climate neutrality by midcentury.[35]

FIGURE 5

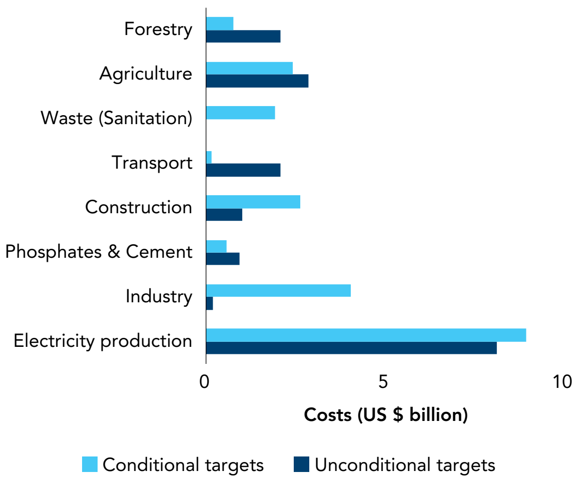
GHG Emissions under the baseline scenario and the conditional and unconditional scenario



Source: Revised NDC, 2021

FIGURE 6

Costs for unconditional and conditional measures by sector

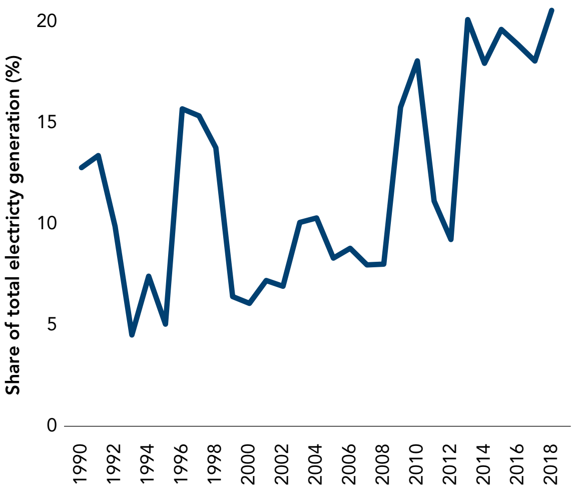


34 Note: Other energy includes crude oil.

35 Government of Morocco (2021), "Stratégie Bas Carbone à Long Terme Maroc 2050"

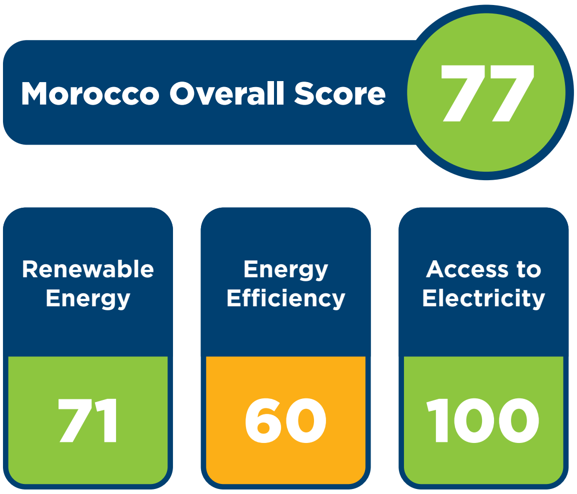
Morocco has taken important steps to decarbonize the energy sector. Morocco announced a planned increase in renewable energy capacity to reach 52 percent of the total power capacity (20 percent solar, 20 percent wind, 12 percent hydro) by 2030.[36] Morocco's long-term ambition is to switch from 80 percent of power generated by fossil fuels to 80 percent renewables in 2050. The government has taken concrete steps toward reaching these goals. For instance, the World Bank's Regulatory Indicators for Sustainable Energy (RISE)[37] indicates that the country stands out in the Middle East and North Africa region, especially in terms of renewable energy regulations. These efforts have led to a successful increase in Morocco's renewable energy as a share of total electricity generation (Figure 7). Morocco has also taken important steps to remove fossil fuel subsidies, except butane. A weak point in Morocco's sustainable energy reform is energy efficiency. While Morocco has emphasized the importance of energy efficiency, energy intensity of the economy has remained mostly stable for the past decade. Energy efficiency also remains the weakest pillar in the RISE index (Figure 8).

FIGURE 7
Renewable energy as a share of total electricity generation



Source: World Bank

FIGURE 8
Morocco's readiness for the energy transition



Source: Regulatory Indicators for Sustainable Energy (RISE)

2.3.3 Challenges ahead for Morocco's low carbon transition

There is a need to further align different climate plans with broader economic, sectoral, and financial policies. Morocco has various climate plans, such as the NDC, the long-term strategy, and the NAP. There are also broader development plans, such as the New Development Model and the 2030 National Sustainable Development Strategy. Moving forward, authorities could face challenges in coordinating the implementation of various strategies and plans, including those at the sector or subnational level.

There are various barriers to Morocco's decarbonization strategy. For example, there are significant delays and rising upfront costs in the construction of Morocco's solar plants, which are increasingly burdening

36 IEA (2019), "Morocco renewable energy target 2030"
37 RISE is a set of indicators intended for use in comparing the policy and regulatory frameworks that countries have put in place to support the achievement of Sustainable Development Goal 7 on universal access to clean and modern energy. The third edition of the RISE report released in December 2020 captures policies and regulations that enhance sustainable energy in the form of 31 indicators distributed among three pillars: access to electricity, renewable energy, and energy efficiency.

state finances. Furthermore, Morocco's electricity market and power generation structure are not conducive to the variability and intermittency of renewable energy supplies. There is a need to restructure the energy systems to provide more flexibility to accommodate an increase in renewable energy capacity, for example, through battery storage and demand-side response.

The private sector's participation in green investments remain low. The World Bank Group Country Private Sector Diagnostic[38] indicated that the business environment in Morocco is not conducive to new firms entering the market. The diagnostic identified the need to promote a level playing field between state-owned enterprises and private firms to foster market competition and encourage the private sector's participation in the green transition. Overall, firms' awareness of climate issues is low, and there are concerns among firms around the high costs and risks associated with green investments.

Morocco could be affected by international regulations, such as the EU's CBAM, if it is slow to make the low-carbon transition. In 2022, the European Council agreed to the CBAM,[39] which puts a carbon price on selected carbon-intensive imports. Since the EU market receives about 70 percent of the Moroccan exports,[40] the CBAM could increase the costs for Morocco's exports to the EU. Nonetheless, given the scope of the CBAM and the nature of Morocco's exports to the EU, preliminary analysis by The World Bank's forthcoming Country Climate and Development Report for Morocco suggests that the total CBAM payments will likely only affect certain targeted industries, such as cement, electricity, and aluminium.

38 IFC (2019), "Creating markets in Morocco: Country Private Sector Diagnostic"
39 European Council (2022), "Council agrees on the Carbon Border Adjustment Mechanism"
40 World Bank (2022), Morocco Country Climate and Development Report.

SECTION 3

Climate Risks for the Financial Sector

This section assesses the impacts of climate physical and transition risk scenarios on the Moroccan banking sector. In line with the previous section, the analysis of physical risks includes a selection of high impact drought and flood scenarios. Transition risk scenarios focus on the introduction of an abrupt carbon price as a proxy for a set of energy transition policies. The presented analyses and accompanying methodologies are partial in nature. The assessment is bounded by data and modeling limitations, which are further discussed in Section 3.1. Figure 9 presents an overview of the assessed scenarios and the transmission channels in and out of scope.

TABLE 2
Summary of assessed scenarios and transmission channels in and out of scope

	Scenario	Transmission channels in scope	Transmission channels out of scope
PHYSICAL RISKS	1. **Three-year national drought** for a variety of RPs a. Historical b. 2030: RCP 4.5 c. 2030: RCP 8.5 d. 2050: RCP 4.5 e. 2050: RCP 8.5	• Credit losses in relevant corporate, consumer, and mortgage portfolios from the following: » Direct and short-term indirect impacts on the agricultural sector (including crop production and agricultural population) » Second-round macroeconomic feedback effects	• Losses from transmission pathways that originate outside of the agricultural sector (e.g., impacts of water restrictions on nonagricultural sectors) • Losses in noncredit portfolios (e.g., bonds, equities, alternatives) • Losses in international exposures
PHYSICAL RISKS	2. **National riverine and pluvial flood** for a variety of flood level RPs a. Historical b. 2030: RCP 4.5 c. 2030: RCP 8.5 d. 2050: RCP 4.5 e. 2050: RCP 8.5	• Credit losses in relevant corporate, consumer, and mortgage portfolios from the following: » Direct physical damages to assets and properties » Short-term indirect impacts from transportation network disruption and labor productivity impacts » Related sectoral disruptions » Second-round macroeconomic feedback effects	• Losses in noncredit portfolios • Losses in international exposures
TRANSITION RISKS	3. **Abrupt introduction of a carbon price** a. \$25/tCO_2 b. \$75/tCO_2 c. \$150/tCO_2 in selection of CBAM sectors	• Loans subject to increased credit risk in corporate portfolios based on sectoral transition risk sensitivity	• Losses from second-round macroeconomic feedback loops • Losses in consumer, mortgage portfolios • Losses in international exposures • Losses in noncredit portfolios

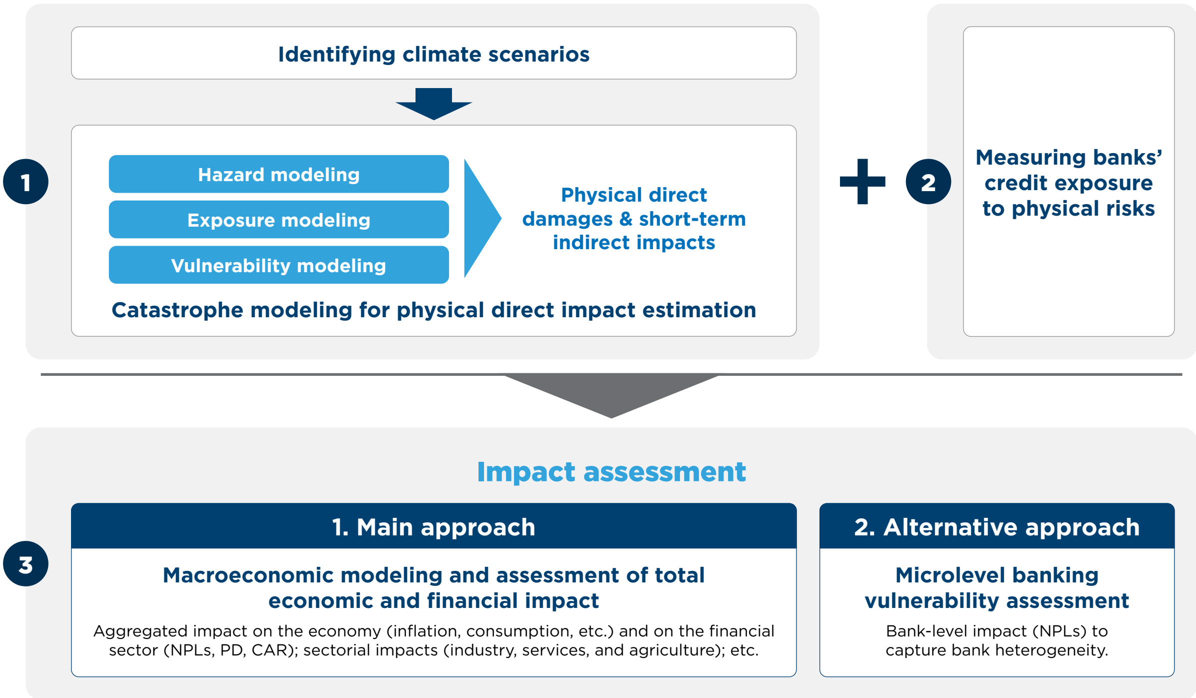
3.1 **Physical Risk**

3.1.1 **Methodology**

A sequenced approach was used to characterize physical climate risks (Figure 9). First, extreme event scenarios were defined (Section 3.1.2), and a catastrophe modeling approach (incorporating modeling of hazard, exposure, and vulnerability) was used to estimate physical direct damages[41] and short-term indirect impacts[42] associated with these extreme events (Section 3.1.3). Extreme event scenarios were characterized for several climate change scenarios corresponding to RCP 4.5 and RCP 8.5 for two time horizons (2030 and 2050).[43] Second, banks' credit exposure to physical risks was analyzed, considering the sectoral and spatial distribution of credit exposures (Section 3.1.4). The physical direct damage and short-term indirect impact estimates and the results of the credit exposure analysis were then used to inform the assessment of impacts on the economy and financial sector.

A macroeconomic modeling approach was developed (Section 3.1.5) to assess aggregated and sectorial climate impacts (both direct and indirect) on the economy and the financial sector. This approach used the output of the catastrophe modeling as an input for quantifying the exogenous shock to the economy. An alternative micro approach (Box 3), which linked physical direct damage estimates with the sectoral and geographical composition of banks' credit portfolios, was taken to estimate bank-level NPL and CAR impacts. The benefit of this approach is that it analyzes climate impacts on individual banks, enabling heterogeneity among banks to be analyzed.

FIGURE 9
Overview of the approach for assessing climate physical risks for the financial sector



41 Definition of direct damages: capital stock destruction for the "agricultural" and "industrial and services" sectors together. Productivity, including crop productivity, is not considered.
42 Definition of short-term indirect impacts: capital flow interruption and impacts on labor productivity.
43 Representative Concentration Pathways are greenhouse gas concentration pathways adopted by the Intergovernmental Panel on Climate Change. The RCPs analyzed in this report include RCP 4.5, which is an intermediate scenario, and RCP 8.5, which is a scenario with very high greenhouse gas emissions. Further explanation available from IPCC AR5 https://ar5-syr.ipcc.ch/topic_summary.php.

3.1.2 **Scenario description**

Several drought and flood scenarios were developed for the physical climate risk assessment. The scenarios were developed for drought and flood, two of the main climate-related perils of concern for Morocco (as outlined in Section 2.2.1). The scenarios were developed based on current and future climate conditions.

Drought scenarios

Five drought scenarios were selected (Table 3): one representing a three-year prolonged national drought event with a 500-year RP under current climate conditions, and four climate change–conditioned versions representing a three-year drought event with a 500-year RP under climate change conditions (RCP 4.5 and RCP 8.5 in 2030 and 2050). In addition to these five scenarios for 1-in-500-year events, drought impacts were also characterized for a broader suite of RPs (2, 5, 10, 20, 50, 75, 100, 250, 500, 1000 years).

TABLE 3
Description of drought scenarios

Current Climate (Historical)	**2030 Climate Projections**		**2050 Climate Projections**	
Scenario A Three-year national drought	**Scenario B** Three-year national drought **RCP 4.5**	**Scenario C** Three-year national drought **RCP 8.5**	**Scenario D** Three-year national drought **RCP 4.5**	**Scenario E** Three-year national drought **RCP 8.5**

- **Current Climate (Historical):** Prolonged drought with RP 500 extending over three years at the national scale starting in Q3 2020. Annual rainfall of less than 200 mm, with smaller farmers primarily affected, increased crop imports and led to a revenue decrease for the Agri-food industry. Within the NGFS framework, this type of scenario is referred to as an acute risk scenario.
- **2030 and 2050 Climate:** Prolonged drought with RP 500 extending over three years at the national scale occurring in 2030 and 2050 under climate change conditions given by the Intergovernmental Panel on Climate Change (IPCC) RCP 4.5 and 8.5 scenarios.

Flood scenarios

Ten flood scenarios were selected (Table 4): five for riverine flooding and five for pluvial flooding, with one scenario for current climate conditions and four climate change–conditioned versions (RCP 4.5 and RCP 8.5 in 2030 and 2050) for each of the flood perils. It is important to note that due to data limitations, these scenarios do not represent an individual event per se (e.g., a 1-in-500-year flood event), but instead represent the level of flooding corresponding to a 1-in-500-year local flood depth nationwide. That is, they represent conditions where all regions are flooded in a short time period, rather than considering the typical spatial extent of an individual flood event, which may only impact one region of the country. This has important implications for the interpretation of results, as the level of impacts that are characterized should not be interpreted as having a 1-in-500-year RP. Nonetheless, although extreme rainfall events causing flooding in Morocco are often localized, it is possible for several different regions to all experience flooding during a short period of time. For example, in 2021, flooding occurred in Casablanca in January, Tangier in February, and Tétouan in March. The spatial distribution of exposures in Morocco is highly concentrated (Section 3.1.4), and hence only a few areas would need to be inundated to result in very high losses. As such, the loss values analyzed in this report can be considered plausible, not necessarily for an individual flood event, but rather for a series of events occurring close to one another in time. However, the RP of these losses may be higher than the 1-in-500-year RP of the levels of flooding shown in this report. In addition to these 10 scenarios corresponding to 1-in-500-year levels of flooding, flood impacts were also characterized for flood levels corresponding to a broader suite of RPs (5, 10, 20, 50, 75, 100, 200, 250, 500, 1000 years).

TABLE 4
Description of flood scenarios

Current Climate (Historical)	**2030 Climate Projections**		**2050 Climate Projections**	
Scenario A RP 500 national riverine (A.1) and pluvial (A.2) flood	**Scenario B** RP 500 national riverine (B.1) and pluvial (B.2) flood **RCP 4.5**	**Scenario C** RP 500 national riverine (C.1) and pluvial (C.2) flood **RCP 8.5**	**Scenario D** RP 500 national riverine (D.1) and pluvial (D.2) flood **RCP 4.5**	**Scenario E** RP 500 national riverine (E.1) and pluvial (E.2) flood **RCP 8.5**

- **Current Climate (Historical):** Two scenarios, riverine and a pluvial flooding corresponding to the 1-in-500-year local flood depth nationwide, hitting Morocco in Q3 2020. Flood duration of two days for pluvial, 30 days for riverine. Primarily affecting urban areas and leading to damages to buildings, contents, and machinery, as well as to the transportation network.
- **2030 and 2050 Climate:** Riverine and pluvial flooding corresponding to the 1-in-500-year local flood depth nationwide, occurring in 2030 and 2050 under climate change conditions given by the IPCC RCP 4.5 and 8.5 scenarios.

3.1.3 **Catastrophe modeling**

Catastrophe risk models were developed for drought and flood to compute direct damages and short-term indirect impacts for the drought and flood scenarios (Section 3.1.2). These models combine three modules: (i) a hazard module, which characterizes the occurrence, intensity, and duration of an event; (ii) an exposure module, which characterizes the assets in the regions of interest; and (iii) a vulnerability module, which estimates the damage for a given hazard intensity for the exposures at risk. The impacts were modelled for both historical climate conditions as well as the set of forward-looking climate change scenarios (RCP 4.5 and RCP 8.5 in 2030 and 2050). Details of the methodology for catastrophe risk modeling for droughts and floods are included in Box 1 and the Annex.

a) Catastrophe modeling results for drought

The estimated direct damages and short-term indirect damages for the "current climate" 1-in-500-year drought scenario, totaling 41.8 billion MAD over the three-year duration of the drought event, are shown in Table 5, with the results for the broader suite of RPs shown in Figure 10. It is important to note that impacts could potentially be higher, as not all potential impacts are captured in the modeling, which primarily focuses on direct impacts on the agricultural sector. Other potential impacts, for example, those associated with water restrictions that also impact nonagricultural water users, are discussed qualitatively in Box 2. The impact of climate change significantly increases the direct and short-term indirect impact of drought. This is seen across the spectrum of

BOX 1

Catastrophe modeling approach for drought and flood

Catastrophe modeling is used to estimate direct damages and short-term indirect impacts by characterizing hazard, exposure, and vulnerability for the drought and flood scenarios.

For drought, the hazard module of the model considers several indices that characterize drought intensity and duration,[44] and a statistical analysis of historical data for the period 1984–2019 is used to analyze the probability of occurrence of events of differing intensity and duration. Exposure is characterized using crop data from the Food and Agriculture Organization Statistics (FAOSTAT).[45] For direct damages, vulnerability is modeled using a regression analysis to develop damage functions that relate drought intensity to reductions in crop gross production value. Short-term indirect impacts are modeled as the combination of (i) increased trade import of cereals due to lower internal production (modeled using a regression analysis of drought severity versus import increases) and (ii) impacts on agricultural population (modeled by scaling the direct damages vulnerability function using data from the The Emergency Events Database [EM-DAT] catalog[46] to estimate the number of people affected and reports of job losses to estimate the number of jobs lost). It is important to note that there are other potential transmission channels through which drought can impact other sectors of the economy, which are not captured in this quantitative modeling. A qualitative description of potential impacts across sectors, including nonagriculture-related sectors, is provided in Box 2.

For flood, the hazard model utilizes Fathom-Global riverine and pluvial flood maps,[47] which show depths at a 90-meter horizontal resolution for 10 standard RPs. Exposure is characterized using two datasets: (i) national capital stock data, spatially disaggregating using population, settlement, and land cover gridded map data;[48] and (ii) a road network map.[49] For direct damages, vulnerability is modeled using Joint Research Centre (JRC) depth-damage curves,[50] applied to the spatially disaggregated capital stock data. Short-term indirect impacts are modeled as the combination of (i) capital flow interruption (estimated based on fraction of the road network map that is damaged and the duration of flooding) and (ii) impact on labor productivity (estimated based on the number of people affected using EM-DAT catalog data).

Scenarios under climate change conditions are modeled by applying hazard adjustments based on changes in country-level extreme climate indices using data from the Coordinated Regional Climate Downscaling Experiment for the Middle East and North Africa region (CORDEX-MENA)[51] and the Modeling System for Agricultural Impacts of Climate Change.[52] Further details of the methodology are included in the Annexes.

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44 Indices are based on data from the Food and Agriculture Organization (FAO) through its web-platform Global Information and Early Warning System (GIEWS) and the Coordinated Regional Climate Downscaling experiment for the Middle East and North Africa region; FAO-GIEWS, http://www.fao.org/giews/earthobservation/; CORDEX-MENA: https://cordex.org/domains/cordexregion-mena-cordex/
45 FAOSTAT, https://www.fao.org/faostat/en/
46 EM-DAT, https://www.emdat.be/
47 Fathom-Global, https://www.fathom.global/
48 Penn World Table (PWT) capital stock data was disaggregated using Global Human Settlement (GHS) data and Copernicus Global Land Service (CGLS) Land Cover data; PWT, https://www.rug.nl/ggdc/productivity/pwt/; GHS, https://ghsl.jrc.ec.europa.eu; CGLS, https://land.copernicus.eu/global/products/lc
49 OSM, https://www.openstreetmap.org/
50 Huizinga, J., de Moel, H., Szewczyk, W. (2017), Global Flood Depth-Damage Functions : Methodology and the Database with Guidelines. Joint Research Centre (JRC).
51 CORDEX-MENA, https://cordex.org/domains/cordexregion-mena-cordex/
52 MOSAICC, https://www.fao.org/in-action/mosaicc/en/

modeled RPs, with damages amplified for both frequent events and more extreme rare events. For example, for a three-year-long drought event with a 500-year RP, direct damages and short-term indirect impacts increase approximately 40 percent to 58.6 billion MAD under the RCP 4.5 for 2050 scenario and approximately 66 percent to 69.5 billion MAD under the RCP 8.5 for 2050 scenario. The loss level associated with the 1-in-500-year drought event under current climate conditions is likely to be associated with more frequent events in the future (approximately 1-in-100-year event by 2050 under RCP 4.5). Figure 10 also shows that more frequent events, such as a 1-in-100-year drought, would cause comparable impacts (about a 50% increase) to a much more severe event, such as a 1-in-500-year event (about a 50% increase in impact in comparison to a five-times less frequent event).

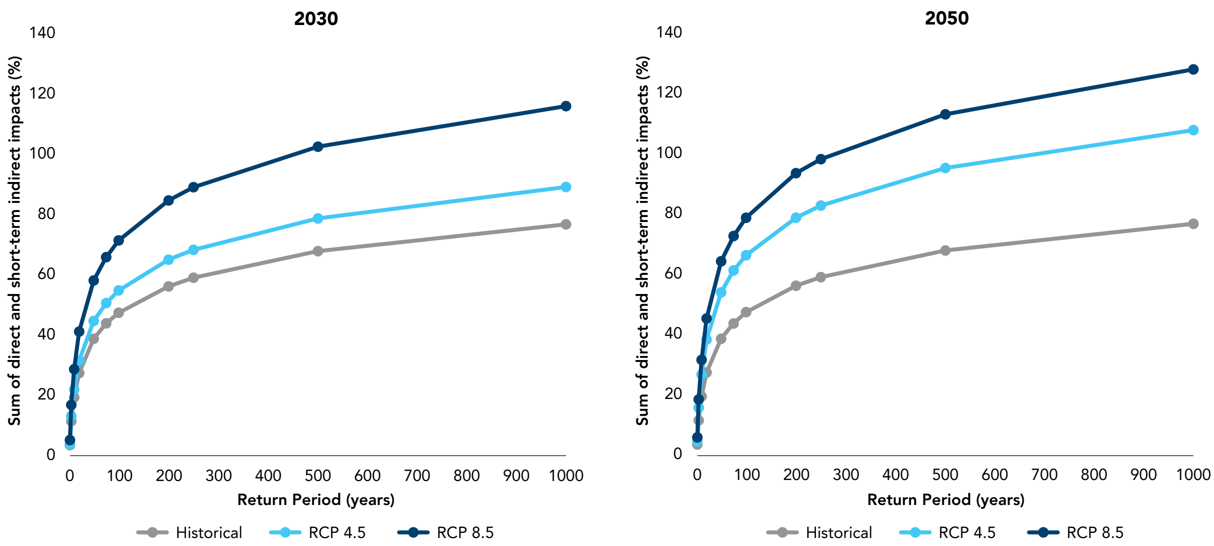
TABLE 5

Impact of 1-in-500-year drought over three-year duration on small and large farms under historical climate conditions (scenario A)

Small farms, direct yearly impacts	Large farms, direct yearly impacts			Short-term indirect yearly impacts	Total direct and short-term indirect impacts (3 years)
	1st year	2nd year	3rd year		
6.69 billion MAD	1.13 billion MAD	4.24 billion MAD	7.2 billion MAD	3 billion MAD	41.8 billion MAD
26.3% of small farms capital stock	3.1% of large farms capital stock	11.8% of large farms capital stock	20% of large farms capital stock	4.9% of total agri capital stock	67.9% of total agri capital stock

FIGURE 10

The effects of climate change on drought impacts for a drought event of three years duration



The x-axis shows the expected frequency expressed in RP, years. The y-axis shows the relative total direct and short-term indirect impacts to capital stock in the agricultural sector. The gray line represents the conditions under a historical climate (i.e., baseline), the light blue line under the climate scenario RCP 4.5, and the dark blue line under the climate scenario RCP 8.5.

b) Catastrophe modeling results for flood

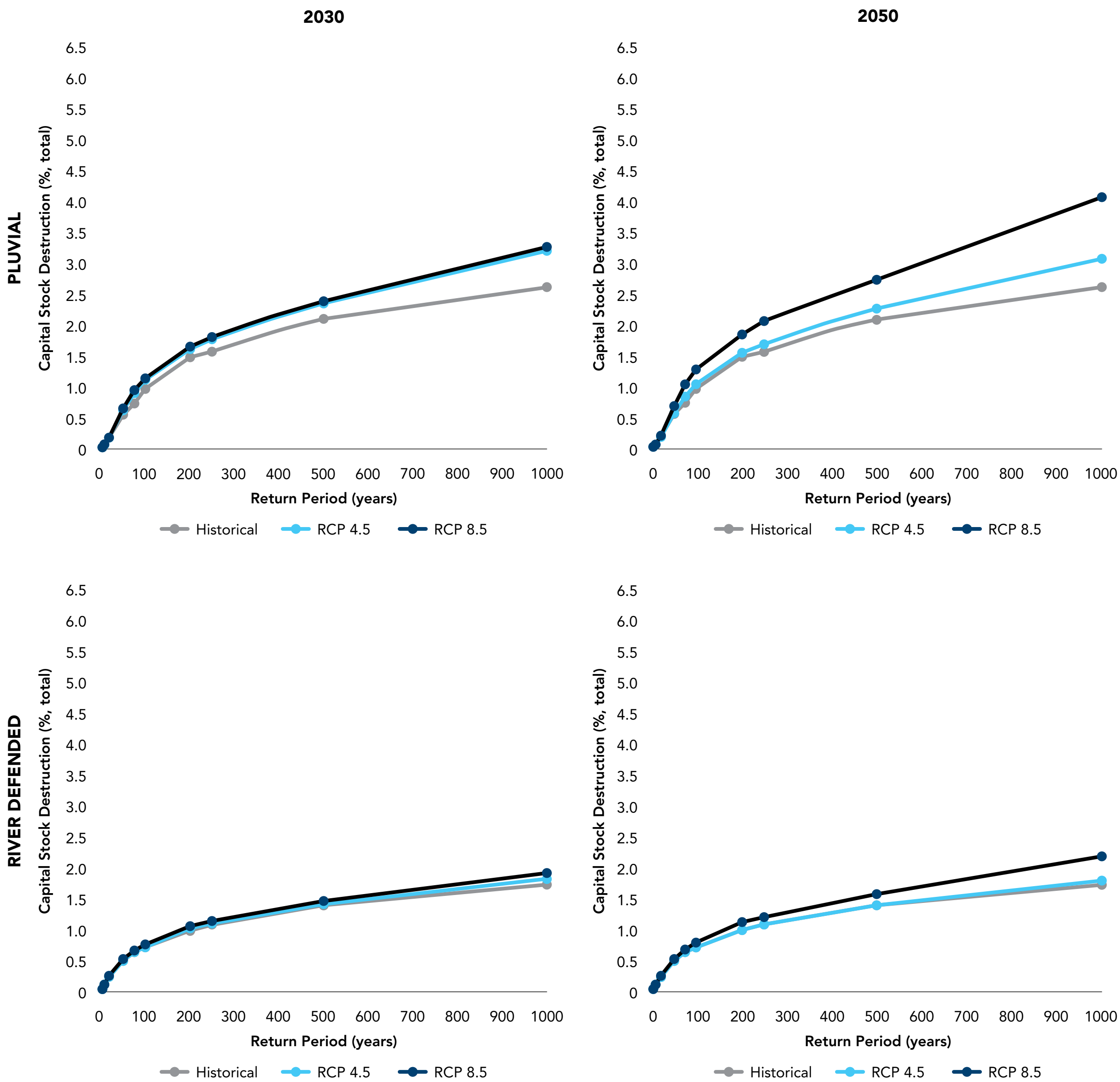
The estimated direct damages and short-term indirect impacts for the "current climate" 1-in-500-year flood level scenario, totaling 80 billion MAD for pluvial flooding and 53 billion MAD for riverine flooding, are shown in Table 6, with the results for the broader suite of flood level RPs shown in Figure 11. The model suggests that climate change increases the total direct damages and short-term indirect impacts from floods. For a 1-in-500-year pluvial flooding, the direct damages and short-term indirect impacts increase approximately 8 percent to 86.7 billion MAD by 2050 under RCP 4.5 and approximately 30 percent to 104.8 billion MAD by 2050 under RCP 8.5. The results for the larger suite of flood level RPs for current and projected future climates are shown in Figure 11, which shows, for example, that a more frequent event such as a 1-in-100-year flooding would cause about half the impact of a 1-in-500-year event.

TABLE 6
Estimated direct and short-term indirect impact of 1-in-500-year flood level scenarios under historical climate conditions (scenario A.1 and A.2)

Scenario	Agriculture (billion MAD % of agriculture capital stock)	Industry and services (billion MAD % of industry/ services capital stock)	Short-term indirect impacts (billion MAD)	Total direct and short-term indirect impacts (billion MAD % of total capital stock)
Pluvial - Current Climate	12 billion MAD	61 billion MAD	7 billion MAD	80 billion MAD
	2.89%	1.8%	/	2.11%
Riverine - Current Climate	11.95 billion MAD	36.70 billion MAD	4.69 billion MAD	53.33 billion MAD
	2.85%	1.08%	/	1.4%

FIGURE 11

The effects of climate change on flood impacts for both pluvial and riverine flood types

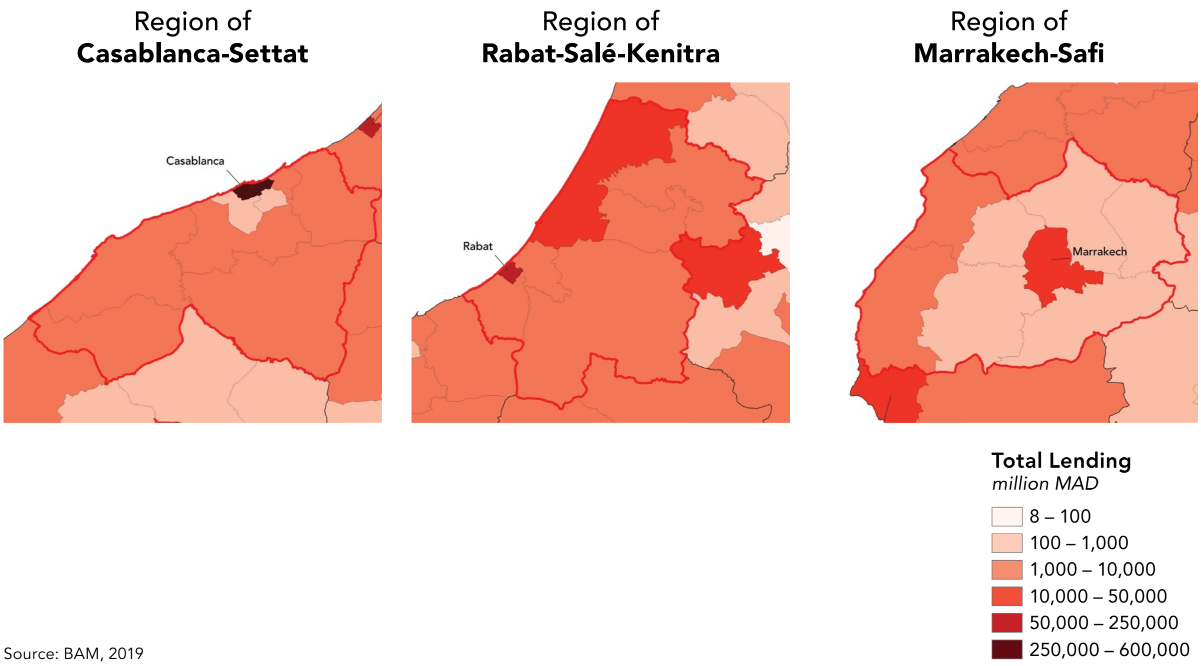


The x-axis shows the RP, years, of the modeled level of flooding (river defended and pluvial). The y-axis shows the relative impacts to capital stock in the economy (direct plus short-term indirect). The gray line represents the conditions under a historical climate (i.e., baseline), the light blue line under the climate scenario RCP 4.5, and the dark blue line under the climate scenario RCP 8.5.

3.1.4 **Banks' exposure to physical risks**

Banks' credit portfolios are geographically concentrated in a few regions, with high sectorial concentration for some banks. Credit exposure in Morocco is heavily concentrated geographically (Figure 12). More than 60 percent of total credit is concentrated in the province of Casablanca. Casablanca, Rabat, and Marrakech account jointly for 77 percent of total credit exposure. In contrast, the 50 smallest provinces account for only 3.5 percent of total credit exposure. In addition, some banks have credit portfolios that are highly concentrated within a few sectors. These geographical and sectoral credit concentrations have important implications for banks' climate risk exposures as outlined below.

FIGURE 12
Bank credit exposure by region



Source: BAM, 2019

While droughts and floods can potentially directly and/or indirectly impact all sectors, some sectors are likely to be more severely impacted, with a collective exposure of around one third of sectoral lending to particularly high climate physical risks. As detailed in Box 2, shocks caused by drought directly affect the agriculture sector. Crop producers and livestock farming suffer direct economic losses arising from a decrease in production/yields, potential losses of animals, distressed sales of livestock units, and increased cost of livestock feed imports. The effects of drought are propagated through the agricultural value chain and spill over to other connected sectors such as food transport, storage and processing, agroindustry, as well as manufacturing and trade. Droughts can also directly impact the water sector (and, in some cases, sectors such as mining, which use raw water supplies) due to decreased availability of raw water supplies and deterioration of source water quality, with spillover effects causing indirect impacts on industries with high water consumption, such as textile and leather manufacturing. Similarly, shocks caused by floods can enter the economy by directly damaging capital stock in all sectors that have assets that are located in the area hit by the disaster (e.g., on the floodplain in the case of riverine floods) and do not have adequate protective measures. Flood shocks can also ripple to other economic activities such as manufacturing, tourism, trade, and services. As a consequence, all economic agents and enterprises operating in the regions hit by the shock or in connected sectors can be subject to significant financial losses that can impact their ability to meet repayment obligations. Of the sectors at risk from climate-related shocks, agriculture and agro-industrial and food processing are particularly at risk (e.g., from drought). These sectors account for almost 8 percent of bank lending. The tourism sector and household mortgages are amongst other sectors that are particularly at risk (e.g., from floods, and via indirect impacts of climate shocks on household finances and tourist dynamics). These sectors account for an additional 25 percent of bank lending. Collectively, this indicates that approximately a third of lending in Morocco is to sectors with particularly high climate risks (though other sectors are also likely to be impacted directly or indirectly by climate risks).

BOX 2

Description of potential direct and indirect impacts of physical climate shocks by sectors (droughts and floods)

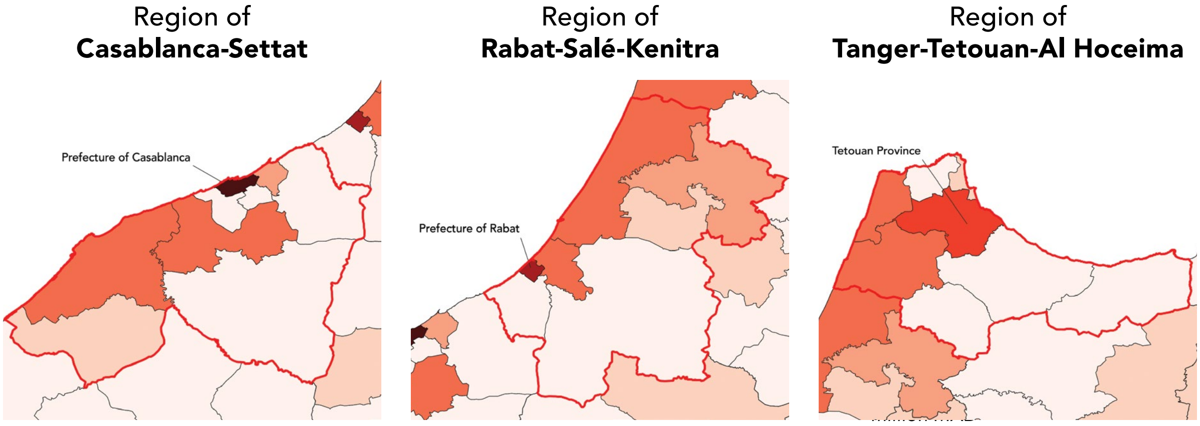
Sector	Sectorial distribution of credits, % of total credit	Drought potential impacts	Flood potential impacts
Agriculture and fishing	4.1%	**Direct and indirect.** Droughts directly impact crop production and deplete livestock herds.	**Direct and indirect.** Floods can destroy crops and cause livestock losses.
Energy and water	4.5%	**Direct and indirect.** Drought can reduce the availability and quality of water supplies and increase demand. Drought can cause disruptions in the energy supply and increase energy demand.	**Direct and indirect.** Floods can disrupt the production and distribution of energy and damage water treatment and distribution infrastructure.
Mining and quarrying	2.3%	**Direct,** particularly for mining operations with high water consumption.	**Direct.** Floods can disrupt the production and flow of goods by directly affecting production sites and infrastructures.
Manufacturing	9.1% (3.4% agrifood + 0.7% textile + 1.2% chemical + 2.1% mechanical, metallurgical & electrical + 1.8% other)	**Indirect,** particularly for agroindustry (via impacts on the agriculture sector) and industries with high water consumption such as textile and leather (via impacts on the water sector).	**Direct and indirect.** Floods can disrupt production and flow of goods by directly affecting production sites and infrastructures, as well as by affecting workers' capability to work or to reach the site of work.
Tourism and hospitality	1.5%	**Indirect.** Lower water levels can affect the availability of recreational activities and associated tourism.	**Direct and indirect.** Floods can directly damage facilities and local infrastructure (including accommodation, restaurants, and cultural heritage sites) and cause declines in visitors' numbers and consequent business losses.
Transport and communication	4.2%	**Indirect,** particularly for food transportation (via impacts on the agriculture sector).	**Direct and indirect.** Transportation networks and infrastructures can be impacted by floods, directly (by damage to infrastructures and vehicles) and indirectly (e.g., by rerouting traffic).
Construction	10.2%	**Direct and indirect.** Drought can generate damage to buildings due to soil desiccation.	**Direct and indirect.** Floods can generate physical damage and affect workers' capability to work or to reach the site of work. Positive impacts may also appear in the medium term with the increase in demand for the reconstruction of destroyed buildings and infrastructures.
Wholesale and retail trade	6.4%	**Indirect,** particularly for food trade.	**Direct and indirect.** Floods can disrupt the flow of goods and impact storage facilities and commercial spaces.
Other services	13.6%	**Indirect.** Drought can disrupt the flow of services, particularly connected to the food industry.	**Indirect.** Floods can disrupt the flow of services.
Residential real estate	23.8%	**Direct and indirect.** Drought can generate damage to buildings due to soil desiccation.	**Direct and indirect.** Floods can damage or destroy buildings.

A significant share of banks' lending is in areas that are prone to droughts. Due to more frequent and severe droughts as a result of climate change, large parts of Morocco will see a significant reduction in agricultural output, especially for rain-fed crops such as wheat.[53] Based on data from the Agricultural Stress Index System, the provinces/prefectures with the highest historical frequency of severe droughts during the period 1984-2022 include Essaouira, Chichaoua, Marrakesh, and El Kelfa Des Sraghna in the Marrakech-Safi Region, and Taroudannt and Tiznit in the Souss-Massa Region. Collectively, these areas account for more than 14 percent of lending outside of Casablanca and Rabat, though other parts of the country are also highly prone to droughts.[54]

A large share of bank lending is also in provinces that are estimated to see severe damages of extreme (1-in-500-year) pluvial or riverine floods. The model[55] estimates that 42 of Morocco's 76 provinces would experience damages of more than 1 percent of the province's total capital stock, following a 1-in-500-year riverine flood, including the provinces of Rabat, Salé, and Marrakech. Casablanca's total capital stock is expected to experience damages of 0.9 percent. A 1-in-500-year pluvial flood could even cause damage of more than 1 percent of capital stock in almost all provinces (74 out of 76). At the aggregate level, 82 percent of credit exposures are located in the 10 provinces most affected by riverine flood, and 73 percent of credit exposures are located in the 10 provinces most affected by pluvial flood (based on the 1-in-500-year RP flood levels). However, note that not all credit exposures located in these provinces would necessarily be individually directly affected by flooding as the flood risk is not uniformly distributed within each province (some areas within a province may have higher flood risk than others). Additional analysis with more granular data (e.g., granular asset-level geospatial data) could help to identify which exposures are most likely to be directly impacted by flooding, which, in combination with sectoral analysis, could further refine the broad estimates of exposure to physical risk presented in this report.

FIGURE 13

Distribution of lending flood risk (size of portfolio at risk of flood)



Source: Authors' calculations based on BAM data. Lending flood risk has been computed by multiplying, at province level, the lending by the relative capital stock destruction caused by a 1-in-500-year riverine flood event.

53 USAID (2016), Climate Change Risk Profile – Morocco, https://www.climatelinks.org/sites/default/files/asset/document/ 2016_USAID_Climate%20Risk%20 Profile%20-%20Morocco.pdf

54 FAO (2023), Agricultural Stress Index System (ASIS), http://www.fao.org/giews/earthobservation/

55 We assess banks' exposure to three different types of flood risks: (i) a defended riverine flood, (ii) an undefended riverine flood, and (iii) a pluvial (i.e., rain-caused) flood. The difference between a defended and undefended riverine flood is that the former considers mitigation measures (system of defenses and control structures such as dam levees and floodwalls) that alter the characteristics of the flood and reduce the probability of flooding in the location of interest. The existence and performance of these mitigation measures under stress is a vital component in assessing the risk of exposure of flood. For each of the three flood types, the expected damage to the capital stock at the province level is calculated by combining hazard (Fathom flood hazard maps have been used, providing flood extent and depth for each scenario), exposure (capital stock and spatial GDP disaggregated by using land cover and JRC's population map), and vulnerability (JRC damage functions have been used). These inputs are used to derive measures of expected flood damage that are expressed in the share of a province's total capital stock.

3.1.5 Macroeconomic and financial modeling

Macroeconomic modeling and transmission channels

A macro approach, using the EIRIN behavioral model, has been developed to assess the macroeconomic and financial impacts of natural hazards in Morocco.[56] The EIRIN model builds on recent related macro modeling literature.[57] It allows direct correspondence between stocks and flows to be traced and displays the dynamic relations of agents and sectors' balance sheets. The EIRIN model is a stock-flow consistent model of an open economy composed of heterogeneous agents and sectors represented as a network of interconnected balance sheet items. As a difference from traditional macroeconomic models (e.g., Dynamic Stochastic General Equilibrium models), the EIRIN model relaxes strong assumptions of agents' perfect foresight and the efficient markets hypothesis that may not hold in the context of deep uncertainty, nonlinearity, and endogeneity of climate risks.[58]

While the input shocks (conditioned to the scenario and estimated by the catastrophe models) exogenously impact the model, the long-term indirect impacts are produced in the EIRIN model by the endogenous reactions of the sectoral and macroeconomic variables over time. Indirect impacts are the results of the computational experiments performed with the EIRIN model reproducing, in a realistic way, the risk transmission channels and connecting the sectors affected by the direct impacts with other sectors and the rest of the economy (Figure 14).

- **In the case of droughts,** the shock directly impacts the capital stock and population of the agricultural sector. Consequently, crop producers and livestock farmers could suffer economic losses arising from a decrease in crop yields. This could spill over 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. A major drought could also increase the prices of agricultural products and thus increase food prices. It is important to note that impacts could potentially be higher, as not all transmission pathways are captured in the modeling, which primarily focuses on transmission pathways via the agricultural sector. Other potential impacts, for example, those associated with water restrictions that also impact nonagricultural water users, are discussed qualitatively in Box 2.

- **In the case of floods,** physical damages to assets and properties (e.g., crops, vehicles, and buildings) could affect several sectors and disrupt key infrastructures such as road and communication networks, which could indirectly generate losses on revenues in sectors such as transport, tourism, and agriculture. Floods could also have broader macroeconomic impacts, such as an increase in sovereign debt levels and a deterioration of sovereign risks.

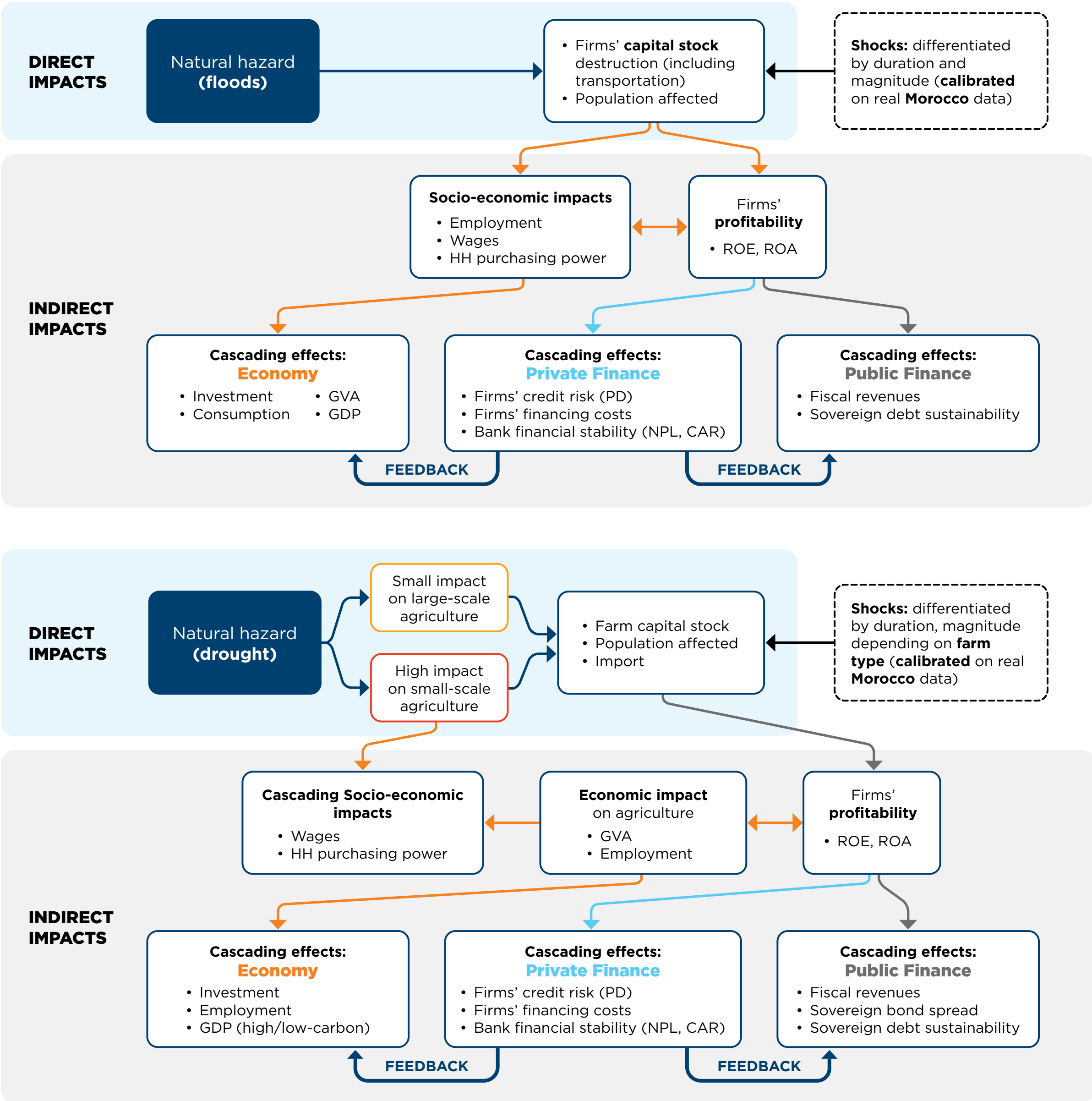
Crop producers and livestock farmers could suffer economic losses arising from a decrease in crop yields. This could spill over and affect broader sectors that are connected to the agriculture sector through supply chain linkages.

56 Essenfelder, A.H., Mazzocchetti, A., Monasterolo, I. (2021), Compound Risk Assessment for DRF: Focus on Climate Physical Risks and the Banking Sector–Methodological Note.

57 Monasterolo, I., and Raberto, M. (2018), The EIRIN Flow-Of-Funds Behavioural Model of Green Fiscal Policies and Green Sovereign Bonds. Ecological Economics, 144, pp. 228–243.
Monasterolo, I. and Raberto, M. (2019), The Impact of Phasing Out Fossil Fuel Subsidies on the Low-Carbon Transition. Energy Policy, 124, pp. 355–370;
Dunz, N., Essenfelder, A.H., Mazzocchetti, A., Monasterolo, I. and Raberto, M. (2021), Compounding COVID-19 and Climate Risks: The Interplay of Banks' Lending and Government's Policy in the Shock Recovery. Journal of Banking & Finance, p. 106306.

58 Monasterolo, I. (2020). Climate Change and the Financial System. Annual Review of Resource Economics, 12, pp. 299–320.

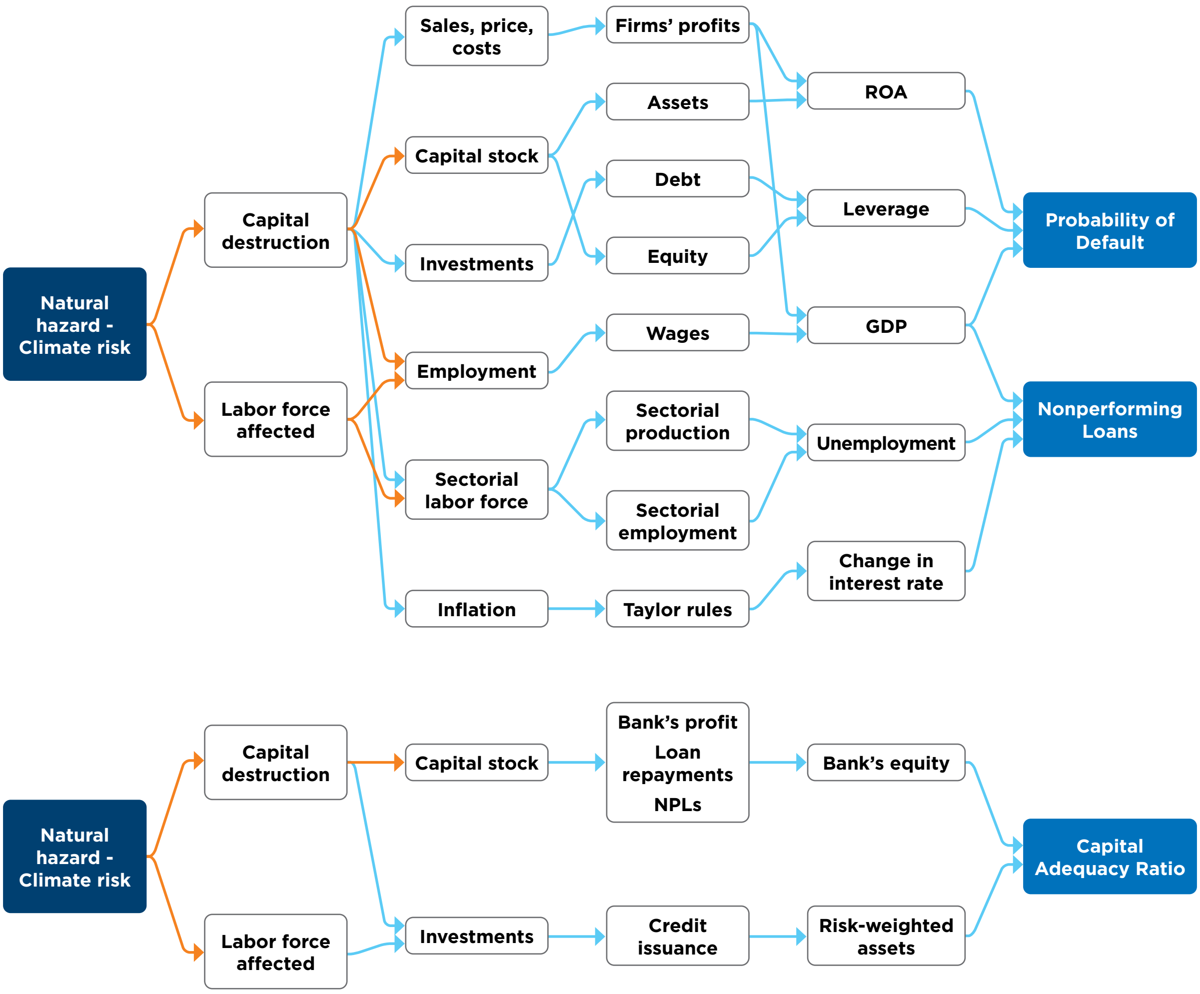
FIGURE 14
Droughts and floods risk transmission channels to the main macrofinancial sectors and variables of Morocco



Note: **Orange arrows** represent the spillover (indirect) impacts on the economy; **light blue arrows** represent spillover (indirect) impacts on private finance; **gray arrows** represent spillover (indirect) impacts on public finance. Source: Authors' own elaborations.

To capture the impact of climate disasters on the financial sector, the EIRIN model considers three financial risk metrics and their modeling solutions: (i) PD, (ii) NPLs, and (iii) CAR. The change over time of these metrics is completely endogenous in the model and dependent on the shock scenario, as predictor variables are endogenously evolving within the simulations. The variables through which a natural hazard shock impacts a financial risk metric include (i) the determinants of each metric and (ii) the sectoral and macrofinancial variables that affect the determinant. The main determinants for PD considered in this analysis are ROA, leverage ratio, and GDP. For NPLs, the determinants include changes in interest rate, unemployment, and GDP. For both metrics, the destruction in capital stock translates into lower production in sectors and thus lower revenues and employment. This leads to an increase in sectoral PD and NPLs since their determinants are affected. For the CAR parameter, the EIRIN model considers banks' equity and risk-weighted assets as the main determinants. Figure 15 illustrates the main EIRIN variables through which a natural hazard shock impacts NPLs, PD, and CAR, including determinants (i.e., change in interest rate, unemployment, and GDP) and the sectoral and macrofinancial variables that affect the determinants.

FIGURE 15
Natural hazard transmission channels to NPLs, PD, and CAR



Note: The **orange arrows** indicate the direct impacts, while the **blue arrows** correspond to indirect and endogenous impacts.

Source: A. Hrast Essenfelder, A. Mazzocchetti, R. Gourdel, and I. Monasterolo, "Compound Risk Assessment for DRF: Focus on Climate Physical Risks and the Banking Sector," unpublished methodological note developed for the World Bank Disaster Risk Financing and Insurance Program, April 2021 – Authors' own elaboration.

The assessment of the macroeconomic and financial impacts of the flood and drought scenarios over a five-year time span show that floods and droughts have different impacts on the economy and finance, both in terms of size and timing. In the following section, we only reported the results for the pluvial flood scenario, as the impacts are higher than those of riverine floods.

Results for drought

Impacts on macroeconomic and real sector indicators

The model results demonstrated that prolonged drought occurring in three consecutive years could directly impact the economic output of the agriculture sector and indirectly impact the industry and service sectors. The agriculture sector is negatively affected by the shock during three consecutive years. Due to the impact of drought on (i) capital stock destruction, (ii) job loss, and (iii) the increase in imports, the output of the agriculture sector trends down during the three consecutive years. The industry and service sectors are also expected to be indirectly negatively affected by droughts. This is mainly due to the impact of droughts on unemployment and wages, which contributes to a decrease in household consumption, which in turn reduces firms' investment and supply in the industry and service sectors.

In the case of the modeled 1-in-500-year drought event under the scenario of historical climate conditions,[59] the lower production in the agriculture, industry, and service sectors is expected to lead to various macroeconomic impacts:

- **A reduction in Morocco's real GDP.** As shown in Table 7 below, the predominant shock of the drought on the agricultural sector is smoothed at the aggregate level, as the sector contributes to only 12.16 percent of the national GDP. However, there is nonetheless a shock to the GDP, with the drought-induced GDP loss (relative to the expected GDP in the case of no drought event) increasing over the period of the drought event.
- **An increase in the unemployment rate,** reaching 11 percent at the end of the shock period (year 5), compared to a baseline unemployment of around 9.7 percent (year 1) over the simulation time span (five years).
- **An increase in the public deficit to GDP ratio,** due to the economic shock and drop in GDP. The public deficit to GDP ratio is estimated to be greater than 4 percent at the end of the drought period (year 5).
- **The indirect to direct damage ratio equal to 1.02.** This means that the damage caused by the drought on capital stock leads to a long-term indirect loss of GDP in the following years of a similar amount.

TABLE 7
Summary of the impact of 1-in-500-year drought on macroeconomic variables by year under scenario of historical climate conditions

Variable	Year 1	Year 2	Year 3	Year 4	Year 5
GDP (loss %)	(0%)	(0.23%)	(0.68%)	(1.32%)	(1.81%)
Consumption (loss in %)	(0%)	(0.24%)	(0.92%)	(1.79%)	(2.53%)
Unemployment rate (absolute)	9.7%	10%	10.4%	10.92%	10.99%
(difference with BAU)	+0%	+0.35%	+0.86%	+1.51%	+1.67%
Public deficit (% of GDP)	3.57%	3.77%	4.03%	4.25%	4.14%
(difference with BAU)	+0%	+0.22%	+0.53%	+0.82%	+0.75%

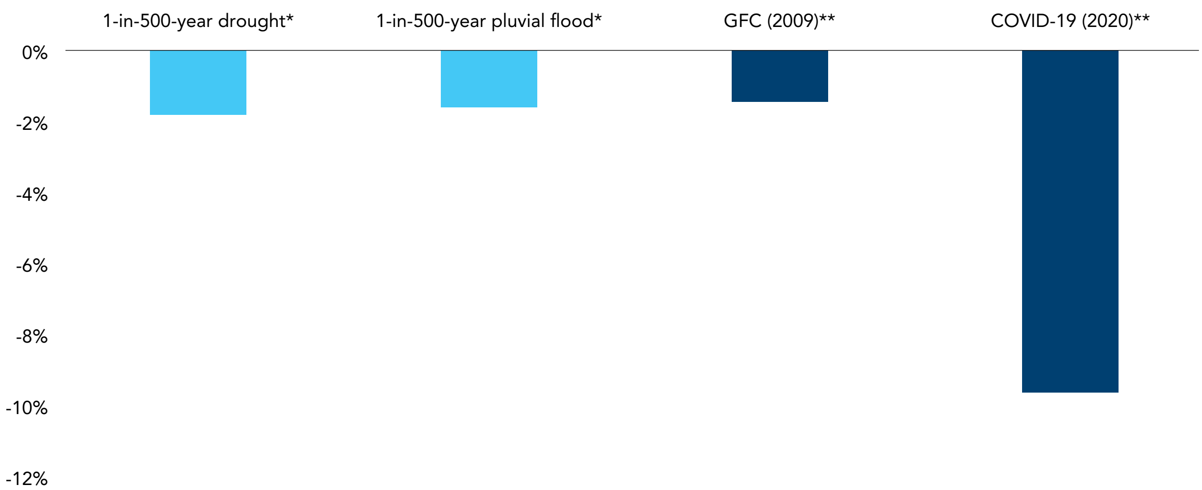
59 Results for the forward-looking climate change scenarios are presented later in this section.

Whilst the macroeconomic impacts are less pronounced for more frequent events, the impacts on GDP for the modeled 1-in-500-year events are comparable in magnitude to other historical economic shocks. For example, the size of GDP losses from the 1-in-500-year drought under historical climate conditions is similar to that of the global financial crisis, though they are less severe than the economic shock associated with the COVID-19 pandemic (Figure 16).

The macroeconomic impacts are less pronounced but still considerable for more frequent, less severe droughts, as highlighted in Annex III.

FIGURE 16

Flood and drought GDP losses (under historical climate conditions) compared to other economic shocks



* Maximum annual impact during the modeled shock period for drought in year 5 and for flood scenario in year 3 of the modeled period for the scenario of historical climate conditions.

** For GFC and COVID-19, the GDP loss is calculated as the differences in the average growth in the three-year period preceding the shock and the growth rate realized in the year of the shock.

Financial risk metrics

Results show that a prolonged drought occurring in three consecutive years has negative effects on the NPL ratio and PD of the agriculture, industry, and service sectors. The agricultural sector is the most negatively impacted by the drought event. As shown in Table 8, in the case of the 1-in-500-year drought scenario under historical climate conditions, the NPL ratio for the agriculture sector increases to 10.5 percent, and the NPL ratio for the industry and services sector increases to 8.5 percent in year 5, in comparison to 7.8 percent in year 1. This result is driven by the shocks in sectoral output, unemployment, and policy rates. The analysis also shows that the PD of the agriculture sector increased by more than 2 percentage points in the last year of the drought. This increase is mainly led by adjustments in the determinants of the PD calculation (i.e., ROA, GDP, and leverage). Furthermore, while drought only directly impacts the agricultural sector, long-term indirect economic effects, driven by higher unemployment and lower wages, lead to lower household consumption, thus worsening the financial risk metrics of the industry and service sectors. Finally, the results of the model show that the CAR decreases during the time span of the simulation, leading to a shock of around 3.3 percent in year 5 (mean across 5 years of 1.3 percent). CAR decrease is driven by the shock on capital stock, labor force, and imports. It is also affected by the increase in credit (due to reconstruction) and the increase in NPL. These financial sector impacts are less pronounced in the case of more frequent, less severe droughts (Annex III).

TABLE 8
Summary of the impact on the financial sector metrics for 1-in-500-year drought scenario under historical climate conditions

Variable		Year 1	Year 2	Year 3	Year 4	Year 5
NPLs ratio						
absolute	**Agriculture**	7.8%	7.96%	8.78%	9.67%	10.53%
difference with BAU		+0%	+0.16%	+0.98%	+1.87%	+2.73%
absolute	**Industry and services**	7.8%	7.84%	8%	8.25%	8.53%
difference with BAU		+0%	+0.04%	+0.2%	+0.45%	+0.73%
PD percentage point *(difference with BAU)*	**Agriculture**	0	0.1	0.62	1.51	2.35
	Industry and services	0	0	0.02	0.07	0.12
CAR percentage loss *(difference with BAU)*	**Banking sector**	0%	(0.15%)	(0.98%)	(2.22%)	(3.35%)

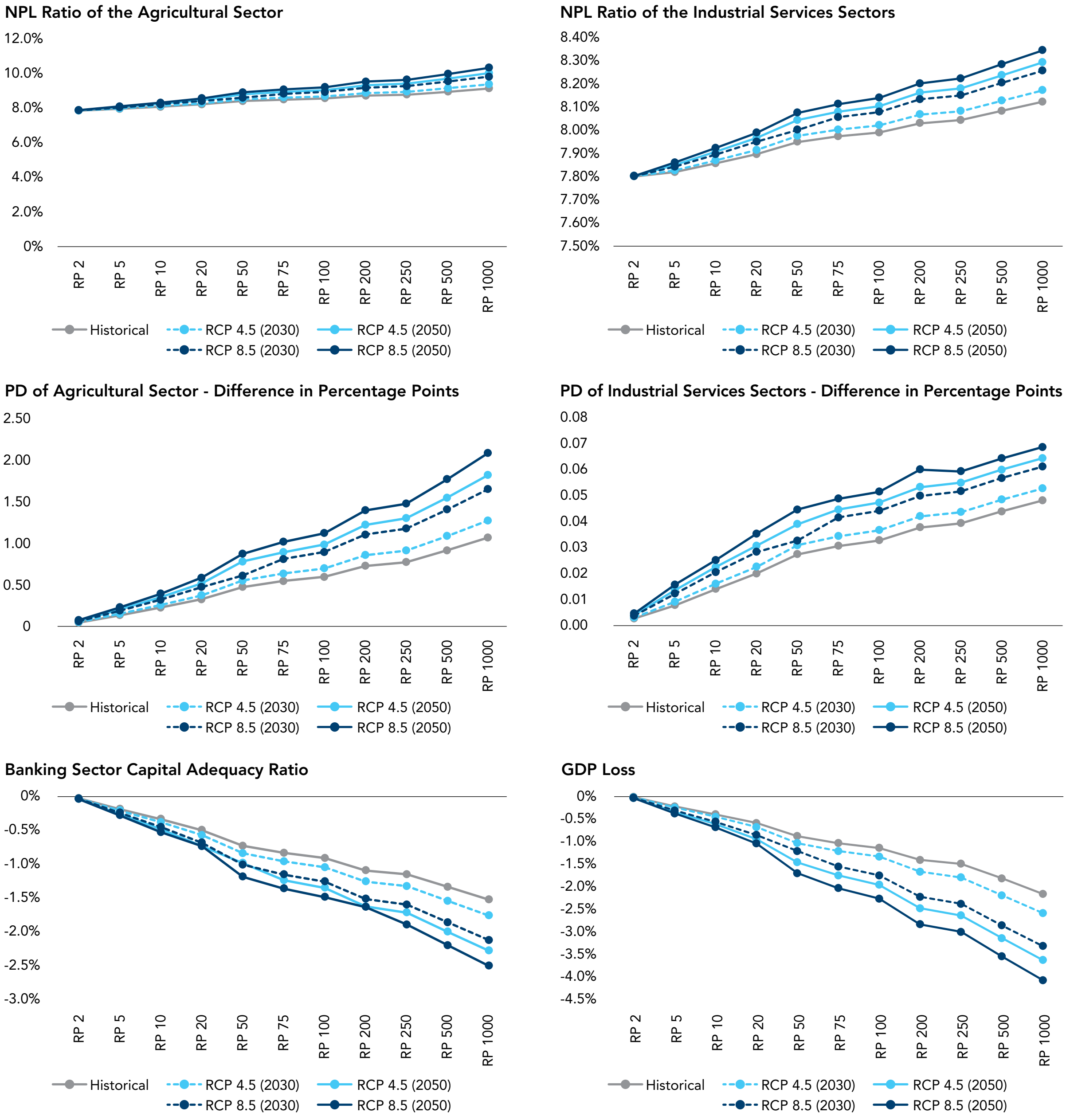
Analysis of drought sensitivity to climate change

An additional set of simulations were conducted to assess the sensitivity of drought impacts to climate change. The purpose of this exercise was to (i) understand the sensitivity of the macroeconomic model, and therefore of the economy, to different hazard severities and (ii) to understand the effects of climate change with respect to current scenarios. To assess the sensitivity to different hazard severities, the model has been run with hazard scenarios of increasing severities from a one-year RP to a one-thousand-year RP. To assess the effects of climate change, in addition to scenarios built from historical climate conditions (including the simulations presented in the previous section; blue line in the plots), two sets of climate change scenarios have been used, specifically following RCP 4.5 and RCP 8.5.

The sensitivity analysis suggests that climate change exacerbates the impacts of droughts on financial sector indicators. As described in the catastrophe modeling section, the direct and short-term indirect impacts of drought increase with the increase of hazard severity from 58.6 billion MAD for RCP 4.5 for 2050 to 69.5 billion MAD for RCP 8.5 for 2050 for a three-year-long 500-year RP drought event. These outputs of the catastrophe (CAT) model have been used as inputs to the macroeconomic model to obtain the indirect impact on the macroeconomic indicators and the financial sector metrics. As shown in Figure 17, climate change could amplify the effects of droughts on financial variables. Notably, the impact of droughts on financial variables could double in the most extreme climate change scenario (RCP 8.5 for 2050) compared to the drought scenario under historical climate conditions . Under this scenario for the 1-in-500-year drought, GDP losses are estimated at 3.5 percentage points, and the mean reduction in CAR across the 5 years of the simulation is estimated at 2.2 percent.

FIGURE 17

Sensitivity of macroeconomic and financial sector metrics to climate change for the drought scenario



The x-axis shows the RP with reference to the natural hazard occurrence. The y-axis shows the changes in CAR; changes in NPL ratio for the agriculture, industry, and services sectors; and changes in PD for the agriculture, industry, and services sectors. The reported results are the average over the period of simulation (five years) for NPLs, PD, and CAR, and the maximum annual impact over the period of simulation for GDP losses.

Results for pluvial floods

Impacts on macroeconomic and real sector indicators

Floods could reduce real GDP and lead to a higher unemployment rate due to lower outputs in the agriculture, industry, and service sectors. The modeling results indicate that floods negatively affect the output of agricultural, industry, and service sectors, with strong impacts in the quarter after the hazards occur. As a result, in the case of pluvial flooding corresponding to the 1-in-500-year flood level under the historical climate conditions scenario, the real GDP decreases by 1.6 percent in the year following the shock, leading to a higher unemployment rate in the aftermath of the shock (10.7 percent). In addition, the results suggest that floods may not significantly affect economic fundamentals, since there is only a marginal impact on domestic and external demand, as well as firms' expectations. This allows real GDP to recover over time as the country increases its investment in reconstruction, eventually catching up with its starting value (before the shock) at the end of the five-year simulation time span. Finally, the results show that the magnitude of long-term indirect impacts is around half[60] that of the direct impacts (the indirect to direct damage ratio amounts to 0.46 for the 500-year riverine flood level current climate scenario [A.1] and 0.41 for the 500-year pluvial flood level current climate scenario [A.2]).[61] The results for a pluvial flood are summarized in Table 9. The macroeconomic impacts are more muted for more frequent, less severe floods, as highlighted in Annex III.

TABLE 9
Summary of the annual macroeconomic impact of the 1-in-500-year pluvial flood level scenario under historical climate conditions

Variable	Year 1	Year 2	Year 3	Year 4	Year 5
GDP (loss in %)	(0%)	(0.28%)	(1.57%)	(0.91%)	(1.17%)
Consumption (loss in %)	(0%)	(0.31%)	(1.88%)	(1.4%)	(0.92%)
Unemployment rate (absolute)	9.7%	10.21%	10.74%	10.01%	9.33%
(difference with BAU)	+0%	+0.56%	+1.2%	+0.59%	+0.01%
Public deficit (% of GDP)	3.57%	3.77%	3.97%	3.57%	3.35%
(difference with BAU)	+0%	+0.23%	+0.48%	+0.14	-0.05%

Financial risk metrics

As detailed in the section on catastrophe modeling, floods are relatively short-duration events, unlike drought, which has a longer-lasting direct impact. As a result, the overall impact of flooding (characterized by a higher drop in the aftermath of the shock, followed by a faster recovery) on financial risk metrics is lower compared to drought, whose direct impact lasts for three consecutive years. Nevertheless, the dynamics displayed in the time series clearly show a worsening of the financial risk metrics as a result of flooding, which is aligned with the negative impact on the agriculture, industry, and service sectors described above. The NPL ratio increases from 7.8 percent in year 1 to a peak of 8.5 percent in year 3 for the 1-in-500-year flood level under historical climate conditions. Also, the PD slightly increases, mainly driven by the determinants of the PD

60 This result differs from the case of drought, in which the indirect to direct damage ratio amounts to 1.02. The difference is mainly driven by the fact that drought impact is assumed to hit the economy over three years (2021–2023), thus constantly shocking the imports, the capital stock, and the labor force of the agricultural sector. This, in turn, leads to relatively higher economic losses compared to the direct impacts.

61 It is worth noting that the indirect to direct ratio compares monetary values. However, the indirect impacts led by the flood also involve other indirect effects that are difficult to be measured in monetary terms (e.g., the increase in unemployment and public deficit to GDP ratio and the increase of NPL ratio and probability of default).

(e.g., ROA, GDP, and leverage). Leverage, in particular, contributes to the increase in PD[62] of the agricultural, industry, and services sectors due to an increase in rebuilding investments in sectors' indebtedness. These financial sector impacts are less pronounced in the case of more frequent, less severe floods (Annex III).

The magnitude of the estimated financial impacts of flooding are comparable with those found in other studies internationally. The analysis in this report estimated a peak decline in the CAR in year 4 of 0.25% for the 1-in-500-year pluvial flood level scenario. The results from the alternative micro approach (Box 3) estimate a decline in the systemwide CAR of 0.6 percentage points (1-in-500-year level of river flood) and 0.4 percentage points (1-in-500-year level of pluvial flood). In comparison, a stress-testing analysis for the Colombian banking system found an average decline in the CAR for Colombian banks between 0.3 and 1.1 percentage points for the flood scenarios investigated (one based on historical floods in 2010 and 2011, and two scenarios with RPs of 1-in-500 years).[63]

TABLE 10
Summary of the annual impact on the financial sector metrics for 1-in-500-year pluvial flood level scenario under historical climate conditions

Variable		Year 1	Year 2	Year 3	Year 4	Year 5
NPLs ratio						
absolute	**Agriculture**	7.8%	7.83%	8.45%	8.49%	8.18%
difference with BAU		+0%	+0.03%	+0.65%	+0.69%	+0.38%
absolute	**Industry and services**	7.8%	7.83%	8.31%	8.34%	8.12%
difference with BAU		+0%	+0.03%	+0.51%	+0.54%	+0.32%
PD percentage point *(difference with BAU)*	**Agriculture**	0	0	0.17	0.24	0.24
	Industry and services	0	0	0.18	0.25	0.24
CAR percentage loss *(difference with BAU)*	**Banking sector**	0%	(0.01%)	(0.1%)	(0.25%)	(0.21%)

Analysis of flood sensitivity to climate change

Similar to the approach taken for droughts, an additional set of simulations was conducted to assess the sensitivity of flood impacts to climate change. As described in the catastrophe modeling section, the direct impact of floods increases steeply with the increase of hazard severity. In addition, climate change acts as an amplification factor for direct and short-term indirect impacts. This is particularly evident, especially in the RCP 8.5 scenario, where there is an increase of about 0.5 percent for RP 500 in 2030 and about 1.5 percent in 2050 compared to the historical scenario. However, it is important to note that this modeling is based on projected changes in extreme precipitation at a country level, but some parts of Morocco may experience different increasing or decreasing trends in these extremes, which may lead to different changes in flood risk.[64]

62 The PD is considered at a sectoral level, not at the individual firm level. Therefore, the PD represents a measure of the overall sectors' probability of default, which may be lower than a single firm's PD.

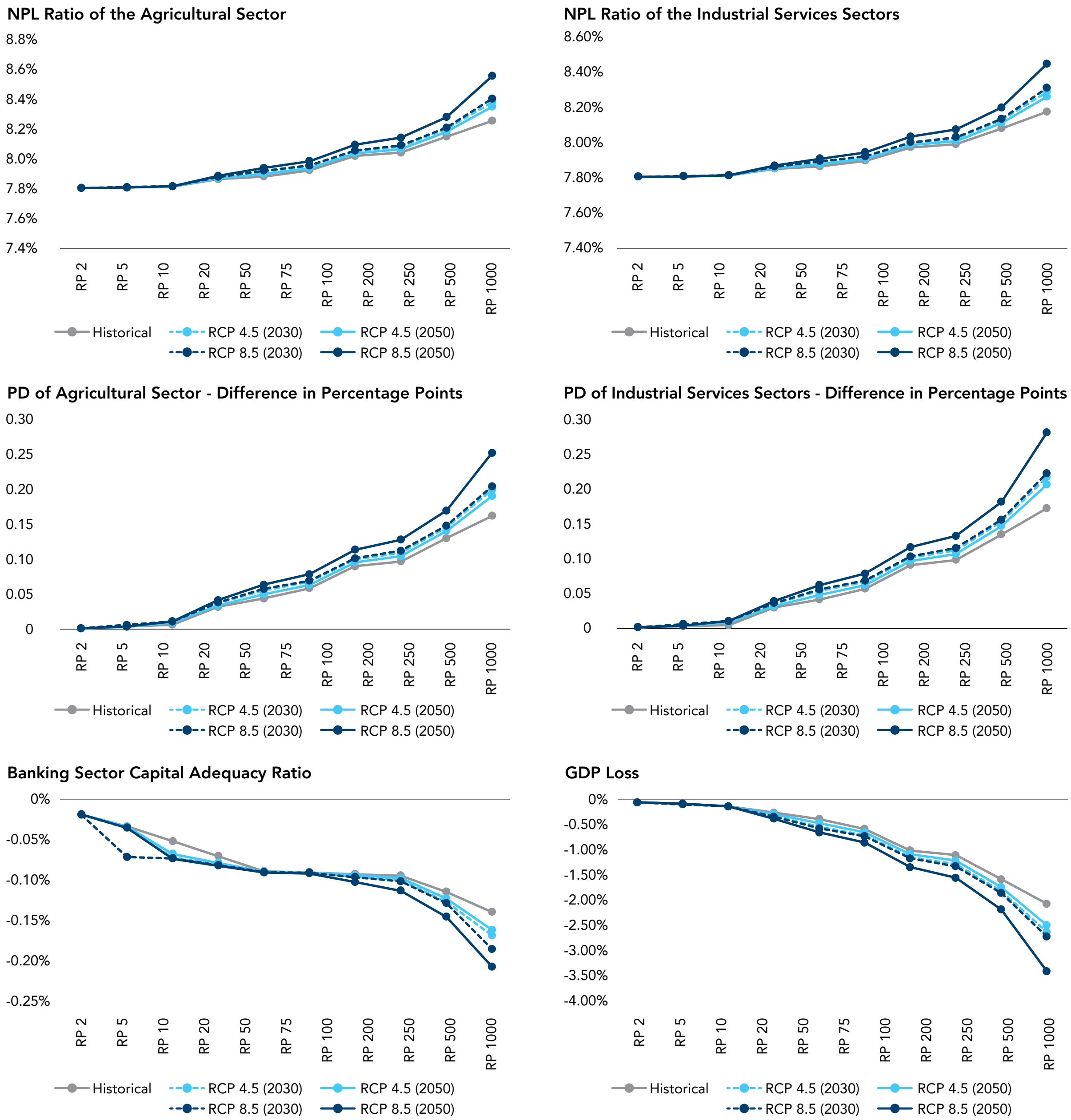
63 Reinders, H.J., Regelink, M.G.J., Calice, P. (2021), Not-So-Magical Realism: A Climate Stress Test of the Colombian Banking System. Equitable Growth, Finance and Institutions Insight. Washington, D.C.: World Bank Group.

64 For example, projections shown in the World Bank Climate Change Knowledge Portal show that the RP of current extreme precipitation events may increase for several parts of Morocco, including over some major cities. World Bank (2022). Climate Change Knowledge Portal, https://climateknowledgeportal.worldbank.org/

The outputs of the CAT model were used as inputs to the macroeconomic model to obtain the indirect impact on the macroeconomic indicators and financial metrics. Figure 18 shows the results of the macroeconomic model for the historical scenario and the climate change scenarios. This analysis illustrates the amplification effects of climate change on financial variables, which are more pronounced for higher hazard severity (i.e., highest RPs).

FIGURE 18

Sensitivity of macroeconomic and financial sector metrics to climate change for the pluvial flood scenario



The x-axis shows the RP with reference to the natural hazard occurrence. The y-axis shows changes in CAR; changes in NPL ratio for the agriculture, industry, and services sectors; and changes in PD for the agriculture, industry, and services sectors. The reported results are the average over the period of simulation (five years) for NPLs, PD, and CAR, and the maximum annual impact over the period of simulation for GDP losses.

BOX 3

Microlevel banking sector vulnerability assessment

This box presents an alternative approach to modeling the impact of natural disasters on banks' balance sheets. This approach links physical direct damage estimates from the CAT model with the sectoral and geographical composition of banks' credit portfolios. The benefit of this approach is that it exploits the bank-level heterogeneity and that the impact on banks is directly linked to their sectoral or regional lending exposure. NPL and CAR impacts can be analyzed for individual banks, enabling heterogeneity among banks to be analyzed. However, while it considers direct impacts of the extreme event scenarios, it does not explicitly quantify indirect impacts. The approach also imposes strong assumptions on the sensitivity of sectoral and regional NPLs to a destruction of the capital stock as well as between job losses and NPLs.

Potential drought impact on the banking sector

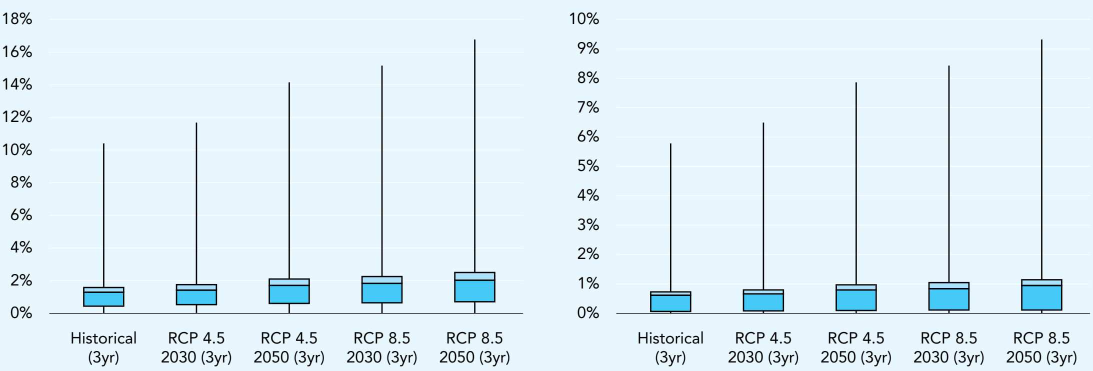
The impacts of droughts are most directly felt in the agriculture sector. The approach therefore assumes that (i) the destruction in capital stock in the agricultural sector results in a proportional share of agriculture loans turning nonperforming and (ii) job losses result in a proportional share of household sector (consumer and mortgage) loans turning nonperforming. The impact on the asset quality of a bank's agriculture, consumer, and mortgage loan portfolio is then aggregated at the bank level, and standard balance sheet stress test methodologies are used to link the NPL shock with the impact on capital adequacy ratio.[65]

The vulnerability assessment results suggest that the different drought scenarios could result in a systemwide increase of NPLs ranging from 2.1 ppts (historical) to 3.3 ppts (RCP 8.5 in 2050). The increase in NPLs is driven by an increase in agriculture sector NPLs (accounting for roughly two-thirds of the total increase) and household sector NPLs. Increases in NPL vary sharply across banks. One bank, due to its large agriculture portfolio, sees NPLs increase by up to 16.8 ppts (under the RCP 8.5 in 2050 scenario). For the other banks, the increase in NPLs is more moderate, ranging from 0 to 5.3 ppts. The relative drivers behind the increase in NPLs also vary substantially across banks. For the larger banks in Morocco, the overall increase in NPLs is primarily coming from the deterioration in the large household loan portfolio rather than the small agriculture loan portfolio.

FIGURE 19
Potential impact of droughts on the banking sector under different scenarios

a. Change in NPLs
(NPLs to total gross loans, ppt)

b. Change in CAR
(ppt)



Note: The assessment uses the five drought scenarios introduced in Section 3.1.2. For modeling the banking sector impact, the three-year cumulative capital stock destruction and loss in employment are used, as outlined in Sections 3.1.2 and 3.1.4.

The resulting systemwide impact on the CAR ranges from 1 ppt (historical) to 1.6 ppts (RCP 8.5 in 2050). The CAR impacts mirror those of NPLs. Again, one bank stands out with a CAR drop of up to 9.2 ppts (under the RCP 8.5 in 2050 scenario). The CAR impact does not exceed 1.5 ppts for other banks even under the extreme RCP scenario.

65 See Annex I for more details on the methodology.

Potential impact of flood on the banking sector

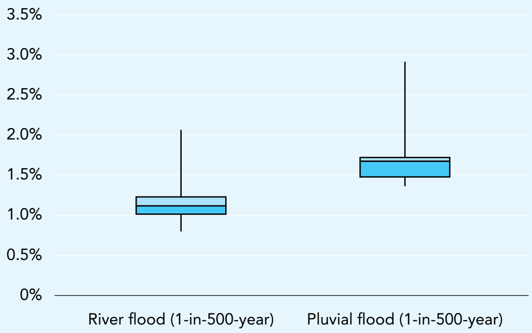
Since, in contrast to droughts, flood impacts are more concentrated geographically, the approach assumes that the destruction in capital stock in a certain municipality results in a proportional share of bank loans in that municipality turning nonperforming.[66] The municipal level NPL impact is then aggregated for each bank, and standard balance sheet stress test methodologies are used to link the NPL shock with the impact on capital adequacy ratio. Similar to the assessment for droughts, the benefit of this approach is that the total increase in banks' NPLs is directly linked to the geographic location of its credit exposure and the location of the economic damage.

The different historic flood scenarios result in a systemwide increase in NPLs ranging from 1.2 ppts (river flood) to 1.7 ppts (pluvial flood). Across banks, the impact of pluvial flooding, which has the largest impact, ranges from 1.4 ppts to 2.9 ppts. The resulting impact on the systemwide CAR ranges from -0.6 ppts (river flood) to -0.4 ppts (pluvial flood). The systemwide CAR would fall from 15.6 percent to between 15 percent (river flood) and 15.2 percent (pluvial flood). For pluvial flooding, the bank-level impact ranges from -0.1 ppts to -0.7 ppts. No bank would reach the minimum CAR threshold of 12 percent due to the floods.

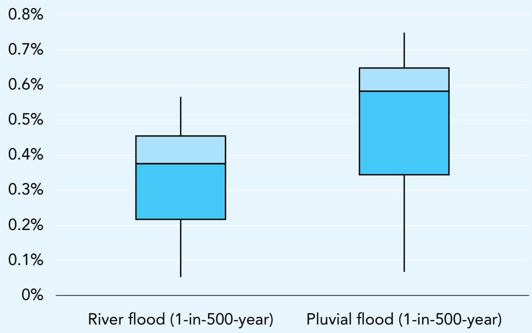
Climate change is likely to increase the financial sector impact of floods over the next decades. As described in Section 3.1.3, climate change is expected to increase the physical damages of floods. The increase in expected damages grows over time and is higher in the scenario with high GHG emission concentration (RCP 8.5). Higher damages to the physical capital stock translate into higher banking sector impacts. The impact increases most strongly for pluvial floods. 1-in-500-year pluvial flooding under the RCP 8.5 climate change scenario is estimated to trigger an NPL increase of 1.9 ppts in 2030 and 2.5 ppts in 2050. This is, respectively, 0.2 ppts and 0.8 ppts higher than the historical impact of such flooding that does not include climate change effects, as discussed in the previous paragraph. The fall in the CAR under these scenarios would increase to 0.7 ppts in 2030 and 0.9 ppts in 2050.

FIGURE 20
Potential impact of floods on the banking sector under different scenarios

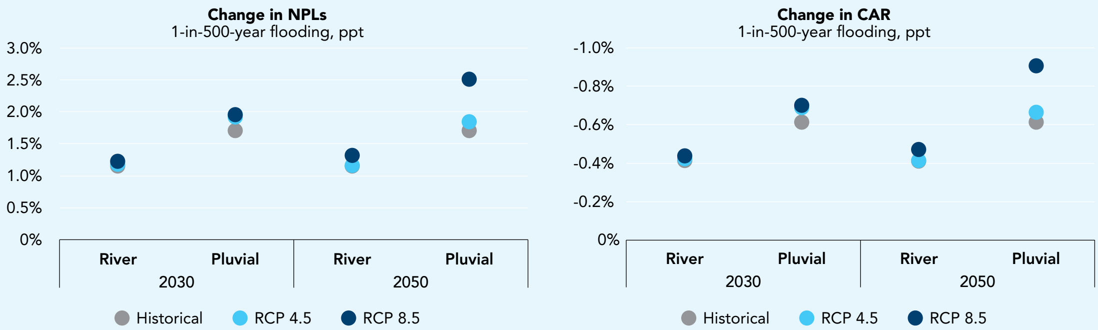
a. Change in NPLs
(NPLs to total gross loans, ppt)



b. Change in CAR
(ppt)



c. Future flood impact on systemwide NPLs and CAR under climate change scenarios



66 The following analysis assumes a one-to-one impact (i.e., for an x percent destruction of capital stock in municipality, y means that for each bank x percent of their loan portfolio in that municipality turn nonperforming.

3.2 **Transition Risks**

3.2.1 **Methodology**

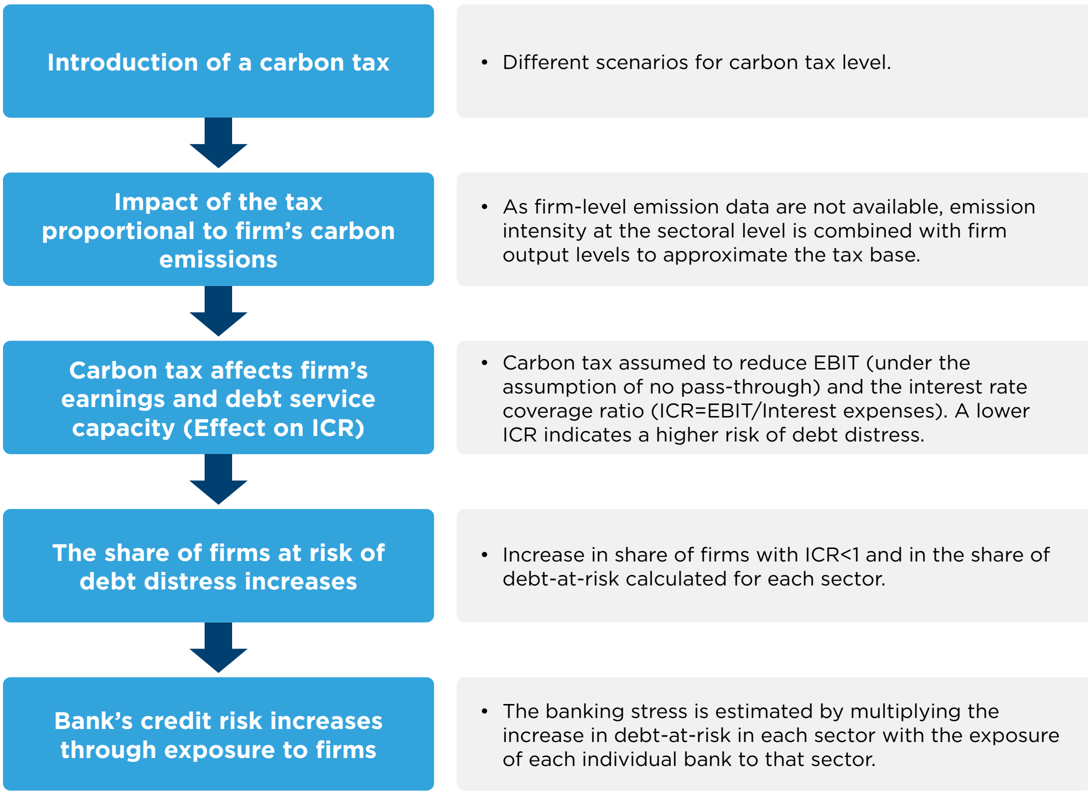
A phased approach was taken to characterize climate transition risks. First, a qualitative assessment of transition risks, transmission channels to the financial sector and an exposure analysis were used to inform the assessment of impacts on the financial sector through the vulnerability assessment. The transition risk vulnerability assessment used in this section follows closely the methodology applied by the International Monetary Fund (IMF) in recent assessments for Colombia and Norway.[67] It follows a multistep approach that first estimates how higher costs of GHG emissions (modeled via a carbon price) affect the financial health and debt service capacity of individual firms and then links this to credit risk in the banking sector. This approach focuses only on the transition impact on nonfinancial corporates and does not model potential impacts on the household sector.

To proxy the impact of higher carbon prices on nonfinancial firms, the assessment uses a simple balance sheet measure that indicates if a firm can cover its annual interest expenditures with its earnings.[68] This measure is called interest rate coverage ratio (ICR) and is calculated as earnings divided by interest expenditure. If the ICR is below 1, a firm does not generate sufficient earnings to cover its interest expenditures and is thus classified as in risk of debt distress. For the transition risk vulnerability assessment, we assume that the higher carbon prices directly reduce a firm's earnings proportional to its level of emissions.[69] As firm-level emission data are not available for Morocco, the assessment uses the sectoral data on emissions per unit of output and links them with a firm's output[70] (under the assumption that emission intensity is the same for all firms within a certain sector) to estimate firm-level emissions. Firm-level emission estimates are then multiplied by the carbon price per unit of emissions under the different scenarios outlined below to calculate the additional financial cost for the firm resulting from climate transition risks. The lower earnings following the carbon price hike reduce the firm's ICR and thus increase the risk of debt distress. For the transition risk vulnerability assessment, the main interest is on firms that were financially sound before the carbon price increase (i.e., ICR >1) but see their ICR drop below 1 as a result of the introduction of a carbon price.

The second step of the vulnerability assessment is to link the deterioration in firms' financial health with the credit risk of banks. Ideally, information on bank-firm specific exposures would be used, but the Orbis data do not identify from which bank a firm obtained the credit. We thus again follow the methodology outlined by the IMF (2021),[71] aggregating the deterioration of a firm's financial health at the sectoral level and linking it with bank-level sectoral exposures. The banking stress arising from the carbon price increase is thus determined by the degree of financial stress in each sector and the exposure of banks to those sectors. It is estimated by multiplying the increase in debt-at-risk in a certain sector with the exposure of each individual bank to that sector. This "exposure at risk" is then scaled by total corporate loans as well as by total bank assets.

67 IMF (2020), Climate-Related Stress Testing: Transition Risks in Norway, WP/20/232; IMF (2021), Climate-Related Stress Testing: Transition Risk in Colombia, WP/21/261.
68 Firm-level data are taken from the Orbis database. It is a worldwide dataset with detailed information on harmonized balance sheets and income statements of firms. The vast majority of firms in the dataset are private, but there are publicly listed firms as well. The reporting in ORBIS has around a two-year lag on average. We use 2018/2019 data. Financial firms as well as firms with missing data are removed from the sample. The final sample includes 40,600 firms.
69 This direct link is based on the "no pass-through" assumption, which stipulates that firms do not adjust the quantity of outputs and inputs and are not able to pass the higher costs on to consumers in the form of higher prices. While some of these effects are likely to occur, a general equilibrium framework would be needed to assess them.
70 Proxied by the Orbis variable Turnover.
71 The methodology deviates slightly from the IMF approach as we use the increase in share of firms with an ICR <1 as well as in debt-at-risk, whereas the IMF paper uses the resulting levels.

FIGURE 21
Methodology for assessing transition risks for the banking sector



3.2.2 Scenario description

The model assumes two different carbon price scenarios. As a proxy for estimating the impact of transition risks for banks, the assessment modeled the impact of an increase in carbon prices through a carbon tax applied to the level of emissions of a firm. Two scenarios were used:

- **In the first scenario, the model assumed a tax rate of $25/tCO$_2$.** This level is discussed by the IMF as the price floor for lower-middle-income countries.[72] This price level is also roughly aligned with the shadow carbon price for the 2030 period, which was used by the Electricity Planning Model under Morocco's Country Climate and Development Report to evaluate the impact of decarbonization pathways in Morocco.

- **The second scenario assumes a higher carbon tax of $75/tCO$_2$.** This level is the midpoint of the carbon price needed[73] by 2030 to implement the Paris Agreement, as set out in the Report of the High-Level Commission on Carbon Pricing and Competitiveness.

The chosen carbon price scenarios are in line with recent NGFS scenarios. The NGFS scenario using Morocco's NDC targets assumes a carbon price of \$29/tCO$_2$ in 2025 that gradually rises to \$74/tCO$_2$ by 2040. The scenario of a delayed transition keeps carbon prices at 0 until 2030 but then sees a jump to \$78/tCO$_2$ by 2035.

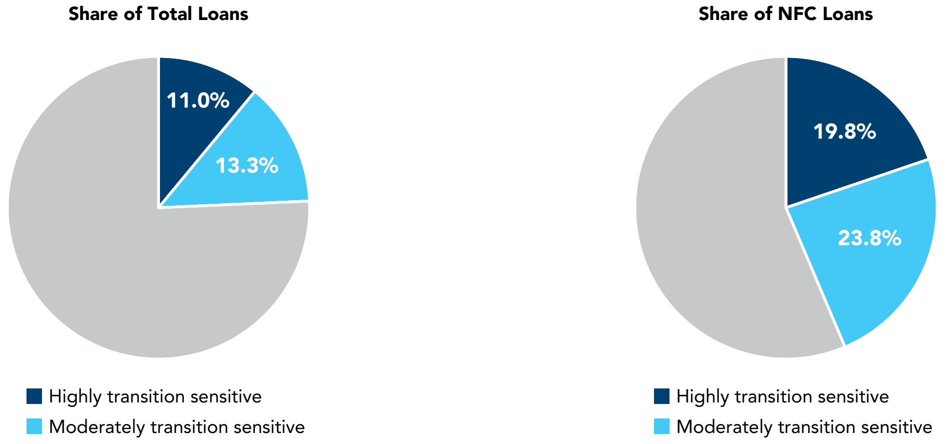
72 IMF (2021), Proposal for an International Carbon Price Floor among Large Emitters.
73 The range is \$50–\$100/tCO$_2$e.

3.2.3 **Exposure**

Overall credit exposure to industries defined as highly or moderately transition-sensitive accounts[74] for 24.3 percent of total loans and 43.6 percent of loans to NFCs. Exposures are highest for the manufacturing (9 percent of total loans), energy and water (5 percent of total loans), and agriculture (4 percent of total loans) sectors. The is high degree of variation in exposure to transition-sensitive industries (Figure 22) and transition risks seem concentrated in small and medium-sized banks that have specialized credit portfolios.

FIGURE 22

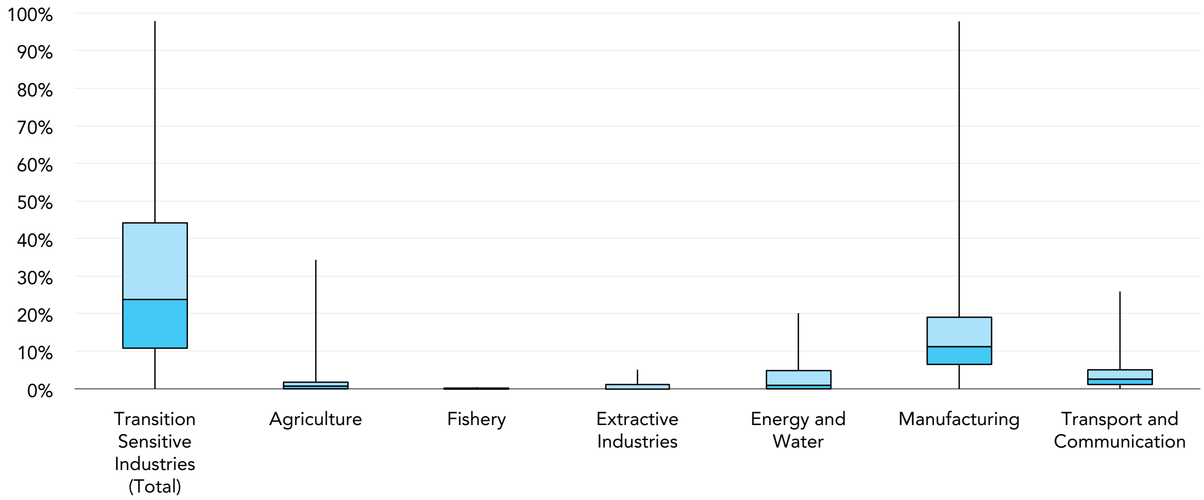
Loan exposure to transition-sensitive industries



Source: Authors' own analysis based on data from BAM.

FIGURE 23

Exposure to transition-sensitive sectors across banks



Note: The center line denotes the median value (50th percentile) across banks, while the blue box contains the 25th to 75th percentiles of dataset. The bars indicate the minimum and maximum values.
Source: Authors' own analysis based on data from BAM as of 2019.

74 Sectors that are considered highly transition sensitive include electricity (ENERGIE ET EAU), transport (TRANSPORT ET COMMUNICATION), and mining (INDUSTRIES EXTRACTIVES). Sectors considered moderately transition sensitive are agriculture (AGRICULTURE, PÊCHE) and manufacturing (INDUSTRIES MANUFACTURIÈRES).

3.2.4 **Transmission channels to the financial sector**

Transition risks can be driven by unanticipated changes in policy, technological disruptions, and market sentiment. The materialization of transition risks can be triggered by a policy decision within the country to reduce GHG emissions. It could also be trigged by changes in international regulations and rules (e.g., the EU's CBAM). Furthermore, transition risks could be trigged by technological advances that reduce the cost of green alternatives, potentially leaving fossil fuels and other GHG-emitting assets stranded. For instance, studies show that the costs of large-scale solar projects have dropped by 85 percent in the past decade and the costs of renewable technologies are continuing to significantly fall every year.[75] Furthermore, the electric vehicle market is gradually becoming more competitive, particularly in select economies such as Germany and France.[76] Transition risks could also be affected by changes in consumer preferences, if consumers decide to switch to green alternatives. This would reduce demand for and the relative price of GHG-emitting assets and reduce the profits of firms producing them. Similarly, international investors may increasingly value green alternatives, which could also drive foreign financial flows away from polluting firms. These developments can lead to a "creative destruction" process where firms that do not transition toward low carbon are forced out of the market.

Based on industries' GHG emissions and GHG emission intensity, industries that are potentially sensitive to transition risks in Morocco could include electricity generation, transport, mining and quarrying, agriculture, manufacturing, and utilities. A crucial first step for understanding potential transition risks for the financial sector is to define the financial sector's exposure to transition-sensitive industries. Several approaches have been developed to identify these sectors.[77] However, these existing approaches rely on granular data on GHG emissions per economic sector that is not available in Morocco. Given these data limitations, this assessment relied on estimates of Morocco's sectoral GHG emission intensity using 2014 GTAP (Global Trade Analysis Project) emissions and production data.[78] The tool collects Scope 1 and Scope 2 emissions for 12 economic sectors and scales them by the production of these sectors.[79] The resulting sectoral emission intensity is measured as tons of CO_2 emission per million of US dollars produced. Figure 25 shows that the most emission intensive sectors in Morocco are the electricity generation sector, which relies heavily on high-emitting, coal-powered power plants, followed by the transport sector, mining and quarrying, agriculture, manufacturing, and utilities. As shown in Figure 24, more than 85 percent of total emissions come from electricity generation, transport, mining, and agriculture.[80,81]

Morocco's revised NDC similarly suggests that industries that may be affected by climate policies include electricity production, industry, and agriculture sectors. As shown in Figure 26, Morocco's revised NDC suggests that decarbonization efforts between 2020 and 2030 will be largely driven by the electricity sector (34.5 percent), the industry sector (28.5 percent), and the agriculture sector (14.1 percent). Any major effort to reduce a country's GHG emissions thus requires a contribution from these sectors, and it is likely that initial policy measures, such as a carbon tax or preference shifts, will disproportionally affect these sectors.

75 World Economic Forum (2021), "Renewables were the world's cheapest source of energy in 2020, new report shows"
76 IEA (2021), "Trends and development in electric vehicle markets"
77 A crucial first step for understanding potential transition risks for the financial sector is to define the financial sector's exposure to transition-sensitive industries. The economic literature offers different approaches to define transition-sensitive industries. Battiston et al. (2017), for example, define a correspondence between sectors of economic activities at the NACE Rev2 4-digit level and five so-called "climate-policy relevant sectors" (fossil fuel, utilities, energy-intensive, transport, and housing) based on their GHG emissions and their role in the energy supply chain. A different approach is taken by the DNB (Vermeulen et al., 2019) where transition sensitivity factors are calculated using a capital asset pricing model combined with sectoral GHG emission intensity along the whole value chain (i.e., not only the GHGs directly emitted by the average firm in each sector but also those embedded in the inputs into their production processes). In this model, an industry's transition sensitivity factor depends on how much its stock returns or market risks react to changes in the price of carbon charged on its embedded emissions. Both approaches, however, rely on granular data on GHG emissions per economic sector.
78 Aguiar, A., Chepeliev, M., Corong, E.L., McDougall, R., Van der Mensbrugghe, D. (2019), The GTAP Data Base: Version 10. Journal of Global Economic Analysis, 4(1), pp. 1–27.
79 Emission data used (based on GTAP) are primarily focused on CO_2 but also include three types of non-CO_2 GHGs: CH_4 (methane), N_2O (nitrous oxide), and the group of fluorinated gases (F-gases).
80 Data taken from the from The World Bank's Emissions Intensity and Trade Exposure.
81 Data for the European Union show similarly that three-quarters of total GHG emissions come from only five economic sectors: electricity generation, manufacturing, transport, agriculture, and water supply.

FIGURE 24
Total GHG emission by industry

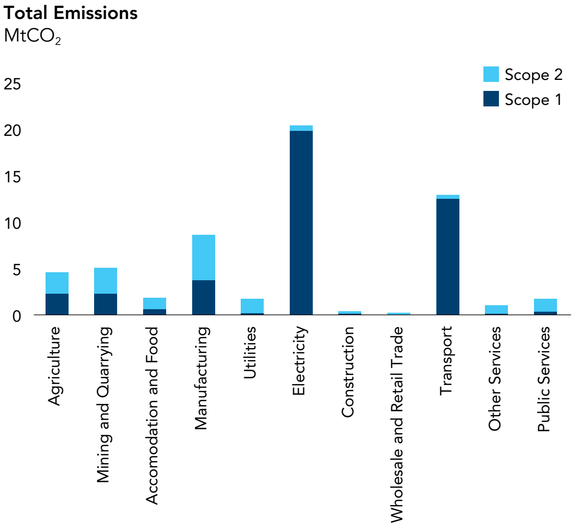
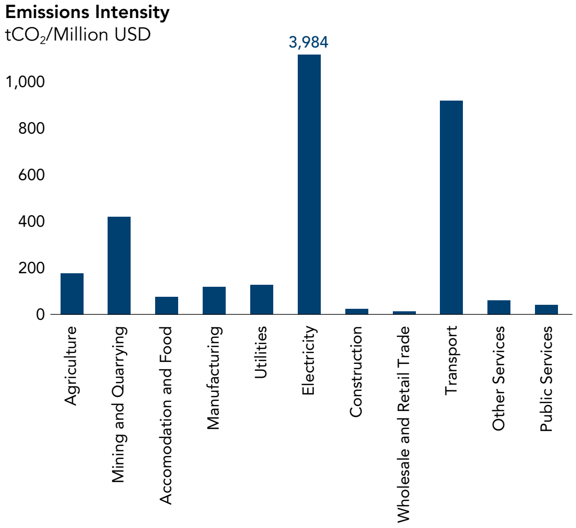
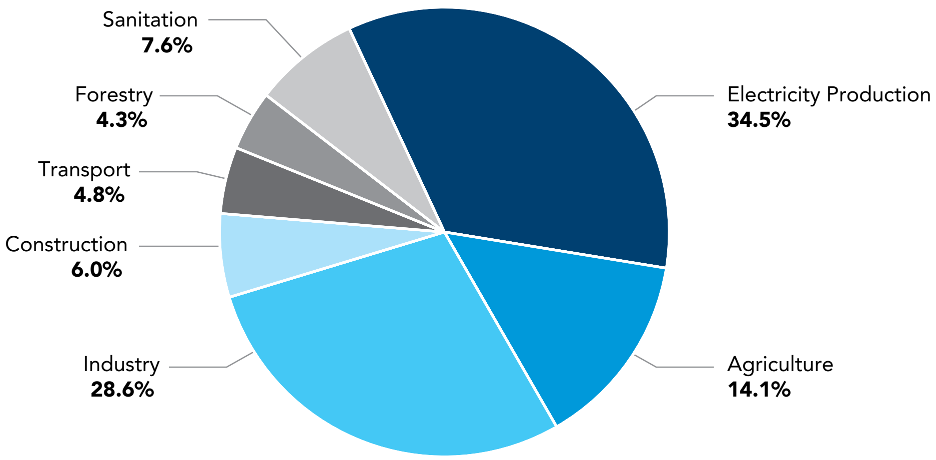


FIGURE 25
GHG emission intensity by industry



Source: World Bank EITE Tool, Data source: GTAP Database Version 10

FIGURE 26
Contributions of the different sectors to the 2020–2030 mitigation target under the revised NDC[82]



Source: Revised NDC, 2021

Transition-sensitive industries may also include those affected by the EU's CBAM, such as industries associated with the production of cement, electricity, and aluminum. Since almost two-thirds of Moroccan exports go to the EU, it may be important to assess the impact of the EU's CBAM on Morocco's banking sector. The likely candidates to be covered by the EU CBAM from the outset of its introduction include cement, steel, aluminum, fertilizers, and electricity. Given the nature of Morocco's exports to the EU, preliminary analysis by the World Bank and ECRST suggests the impact of CBAM is likely to be most pronounced in selected

82 This includes unconditional and conditional NDC targets.

industries. For cement, the CBAM payment share of current prices would be high (54.3 percent when both direct and indirect emissions are considered, and 54.1 percent when only scope 1 emissions are considered). For electricity, the CBAM payment share of current prices is also high (47 percent when both direct and indirect emissions are considered, and 26 percent when only direct emissions are considered). For aluminum, CBAM payments would represent about 22 percent (with both direct and indirect emissions) of total payments but only 5 percent if only direct emissions are considered. Other industries that are expected to receive CBAM payments include fertilizers and crude steel, although the share of total CBAM payments is expected to be lower.

The assessment uses industries' GHG emission intensity, as well as industries that are targeted by climate policies as proxies for identifying the main transition-sensitive industries. The assessment combines information on banks' sectoral lending distribution with estimates on sectoral emission intensity to estimate banks' credit exposure to transition risks.[83] In particular, the assessment defines sectors with an emission intensity above 300 tons of CO_2 per million US dollars as *highly transition sensitive* and sectors with an emission intensity between 100 and 300 tons of CO_2 per million US dollars as *moderately transition sensitive*. Applying these thresholds to BAM's classification scheme, sectors that are considered *highly transition sensitive* include electricity (ENERGIE ET EAU), transport (TRANSPORT ET COMMUNICATION), and mining (INDUSTRIES EXTRACTIVES). Sectors that are considered *moderately transition-sensitive* are agriculture (AGRICULTURE, PÊCHE) and manufacturing (INDUSTRIES MANUFACTURIÈRES).[84] These sectors that are identified as "highly" or "moderately" transition sensitive based on their emission intensity are also likely susceptible to changes in domestic and international climate policy changes (e.g., those targeted by the NDC and CBAM), which provides further evidence that these sectors may be sensitive to climate transition risks.

In general, transition risks can primarily affect financial institutions through losses on their credit and investment portfolios. Changes in policy, technological disruptions, and consumer preferences that are unanticipated by the market could increase NPL losses by increasing corporate operating costs and reducing firms' profitability and debt service capacity. The transition to a green economy can also affect banks' investment portfolios through a lower value of banks' equity and bond holdings of affected firms. As investments are usually priced mark-to-market, a reduction in the market price of the underlying asset would require banks to adjust the value on their balance sheet and record a loss on the investment holding. Transition risks could be amplified through macroeconomic feedback loops. Stress testing by the Dutch Central Bank (DNB) has shown that in severe transition scenarios, wider macroeconomic effects may lead to losses in the financial sector.[85] Besides direct impacts on transition-sensitive industries, this includes credit losses on other corporate and household loans (e.g., due to lower growth and higher unemployment) as well as losses due to changing interest rates as set by the central bank.

Given the structure of Moroccan banks' balance sheets, transition risks lie primarily in banks' credit portfolios. Although banks' investment portfolios account for around 20 percent of total assets,[86] almost two-thirds of those present holdings of government securities.[87] Consequently, equity and debt exposure to the private sector stands at less than 9 percent of total assets. In contrast, credit exposure to the private sector accounts for 60 percent of total assets. This implies that credit losses in response to the transition toward a green economy would have the strongest impact on banks' balance sheets.

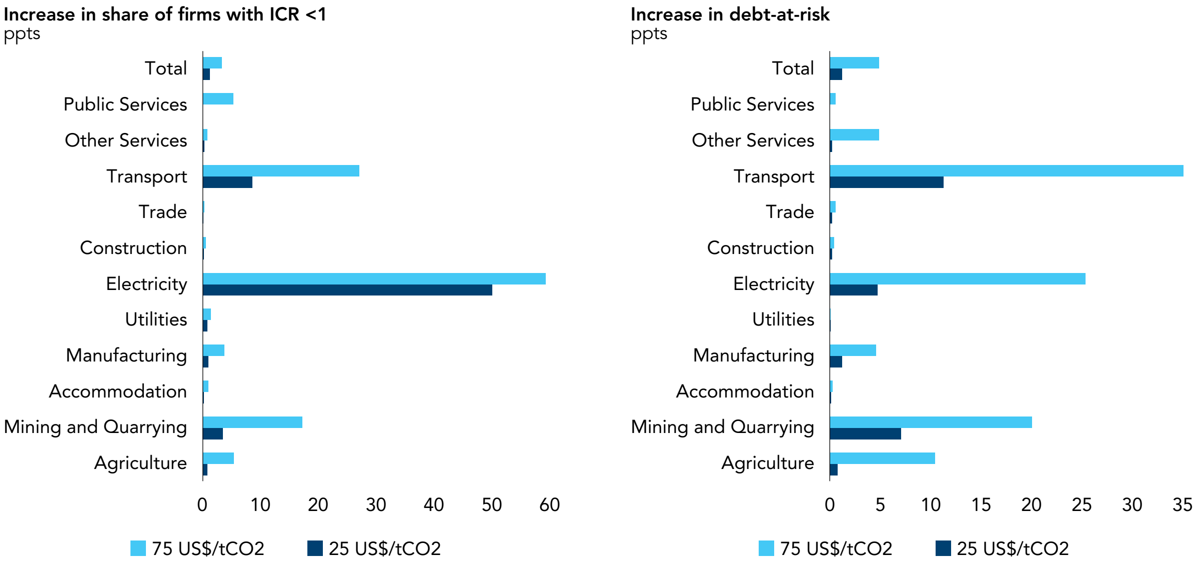
83 BAM provides sectoral exposure data for 16 sectors, which loosely follows the NACE codes used in the European Union.
84 For more details on the matching of the different sectoral classification schemes used in the ETIF tool, BAM's credit classification and the ORBIS data see Annex IV: Sectoral matching.
85 DNB (2018), "An energy transition risk vulnerability assessment for the financial system of the Netherlands"
86 This includes "*Titres de transaction et de placement*," "*Titres d'investissement*," and "*Titres de participation et emplois assimiles*." BAM, Bilan des banques.
87 *Bons du trésor et valeurs assimilées*.

3.2.5 Banking sector transition risk vulnerability assessment

Impact on nonfinancial firms

The model results suggest that the total share of firms at risk of debt distress (i.e., firms with an ICR below 1) increases by 1.1 ppts under the $25/t$CO_2$ carbon tax scenario and by 3.2 ppts under the scenario of a $75/t$CO_2$ carbon tax. The aggregate number, however, hides important differences across sectors. The increase in the share of firms at risk of debt distress is highest in the electricity (49.8 ppts and 59 ppts, respectively), transport (8.5 ppts and 27 ppts), and mining (3.4 ppts and 17.1 ppts) sectors, followed by agriculture (0.8 ppts and 5.3 ppts) and manufacturing (0.9 ppts and 3.6 ppts). For most other sectors, the impact of the carbon price increase is relatively low. The relative impact on the sectors is in line with the emission intensity of these sectors but also reflects the preshock health of the firms and thus their capacity to absorb shocks. The share of firms affected by the carbon price increase does not allow researchers to distinguish between the size of the affected firms and its outstanding liabilities, which are important to assess the risks to the banking sector. The right panel of Figure 27 thus reports the impact of the carbon price increase on debt-at-risk in each sector. Debt-at-risk is defined as all outstanding liabilities of firms with an interest rate coverage ratio of less than one. The total share of debt that is classified as debt-at-risk increases by 1.2 ppts under the $25/t$CO_2$ scenario and by 4.9 ppts under the scenario of $75/t$CO_2$. The increase is larger than that of the share of firms, suggesting that the carbon taxes are affecting firms with higher debt more than smaller firms with low debt.

FIGURE 27
Impact of a domestic carbon price on firms' financial health

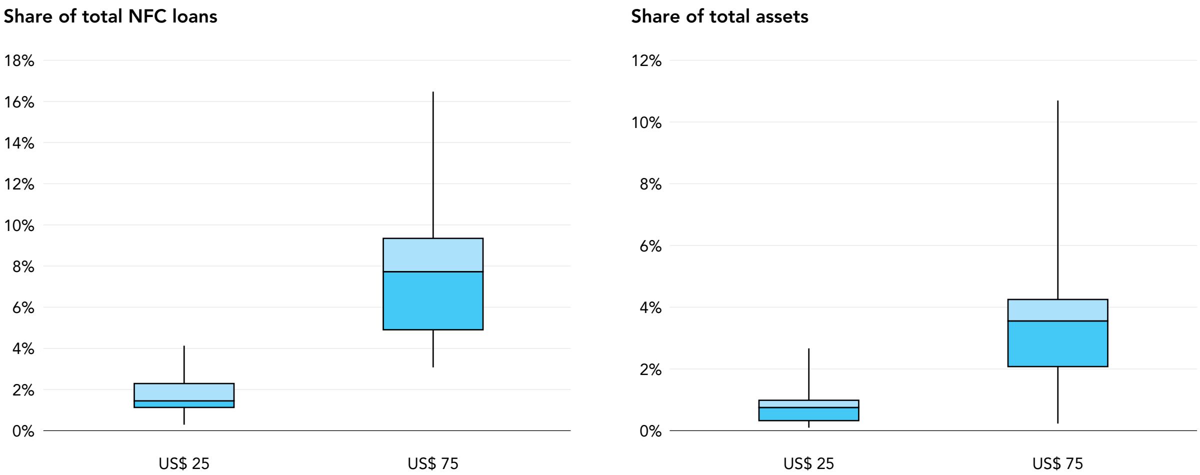


Impact on the banking sector

Systemwide, 1.9 percent of total corporate loans (0.7 percent of banking sector assets) are estimated to be at increased credit risk, following the implementation of a $25/t$CO_2$ carbon tax. A $75/t$CO_2$ carbon tax would put 8.4 percent of systemwide corporate loans (3.1 percent of banking sector assets) at increased credit risk. Figure 28 illustrates the impact of the increase in debt-at-risk of NFCs on the banking sector. As discussed above, estimates for the increase in credit risk are obtained by multiplying the increase in debt-at-risk at the sectoral level with each bank's lending exposure to these sectors. The results vary substantially across banks, reflecting their different sectoral lending focuses, the share of NFC lending in total lending, and the share of lending to total assets. Most of the outliers in terms of either very high or very low increases in credit risk, however, are small banks with specialized portfolios. For the five largest banks, the increase in credit risk is in a range of 2.4 percent to 4.2 percent of total assets under the $75 carbon tax scenario.

The model suggests that the impact of transition risks on the banking sector (proxied through an increase in carbon tax) is substantial but potentially manageable. The estimated impact is of a similar magnitude as what has been estimated for other countries. For example, the IMF estimates that for Colombia a $70 carbon tax puts, depending on the model specification, between 1.2 and 4.9 percent of banking sector assets at increased credit risk.[88] However, it should be noted that there are significant uncertainties associated with the modeling results. On one hand, the results could overestimate the impact of transition risks since the estimates could be viewed as upper bounds due to the simplifying assumption of a no pass-through effect. On the other hand, the impact of transition risks could also be underestimated, given the difficulties of assessing compounding effects and complex feedback loops between climate, macroeconomic, and financial sectors. These caveats and assumptions are further discussed in Section 3.3.

FIGURE 28
Loans subject to increased credit risk (debt-at-risk approach)



Alternative scenario and modeling approaches to assess the impact of the EU's CBAM

As indicated in Section 3.2.1, transition risks can also be triggered by policy actions taken at the international level by major trading partners. To model the potential financial sector impact, we again calculate the impact of higher carbon prices on the health of nonfinancial firms. We model the impact of CBAM on Moroccan firms through a carbon tax applied only on firms in the five sectors initially targeted by CBAM, while all other sectors are not affected. For the five sectors, however, a high carbon tax of $150/tCO_2$ (the level discussed in the EU) is used.[89] The rationale for applying the planned EU carbon tax on Moroccan exporters is

88 IMF (2021), "Climate-related Stress Testing: Transition Risk in Colombia"
89 Using the US-SIC 3-digit classification of the Orbis database, the following sectors are affected: Iron ores (101), Chemical and fertilizer mineral mining (147), Cement, hydraulic (324), Iron and steel foundries (332), Nonferrous foundries (336), Electric transmission and distribution equipment (364), Electric services (491), Gas production and distribution (492).

that CBAM presents a tariff to be paid by the exporters, based on the assumption that the EU importing firm can fully pass on the additional costs to its trade partners and that Moroccan firms do not react by diverting exports to other markets or reducing emission intensity of the production process. These are extreme assumptions, and the estimates should thus be interpreted as the upper bound of the impact. Under these assumptions, the CBAM implementation would result in a 2.9 percentage point increase in debt-at-risk of Moroccan firms. The increase is largely driven by the deteriorating health of firms in the sectors affected by CBAM. Available data on banks' sectoral credit exposure are not granular enough to allow researchers to estimate how the deterioration of the financial health of firms in these sectors would affect individual financial institutions.

3.3 **Caveats and assumptions**

There are several caveats and assumptions that should be considered when interpreting the results of this report's assessment. These considerations are important to consider in the design of future vulnerability or scenario exercises, both by BAM and the banking sector, as shown in the examples below:

- As shown in this report, there is a diverse range of modeling approaches (e.g., a macro approach or a micro vulnerability assessment) for analyzing climate risks for the financial sector. This makes it difficult to decipher results if there are diverging results from different approaches.

- Lack of data is a key challenge. For example, the financial exposure data in Morocco lacks granularity, so it is difficult to have a precise understanding of the actual level of climate risk that financial assets are facing. Furthermore, the lack of accurate and consistent reporting of loss and damage data is a major source of uncertainty and a challenge for CAT model calibration and validation. This contributes to uncertainty in the estimation of damages from floods and droughts.

- On the physical risk side, one of the main challenges for the assessment of the macroeconomic impacts of climate shocks, especially for future scenarios under climate change conditions, stands in their deep uncertainty and nonlinearity.

- On the transition risk side, there are uncertainties around how technologies and regulatory actions will develop in the future, for example, as evidenced by the rapid, unexpected growth in net zero goals and cost reduction for renewable energy. This report used a static carbon price to estimate the impact of transition risks. However, in reality, the implicit price of carbon is likely dynamic and will change over time.

- The transition risk methodology applied in this report does not model potential impacts on the household sector and their spillovers to the banking sector. The transition to a greener economy could affect households through diminished (real) income, as a result of slower GDP growth, higher inflation, or higher unemployment due to structural shifts in the economy. A contraction in households' wealth and income could in turn lead to a deterioration in their ability to service their debts, increasing the credit risk of their banks.

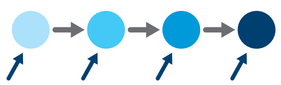
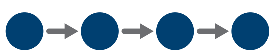
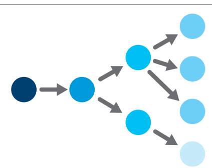
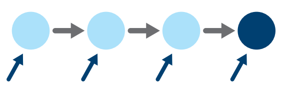
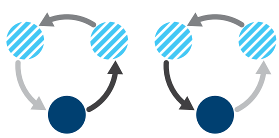
- Interlinkages between physical and transition risks could worsen shocks to the financial system. While transition and physical risks are often modeled separately, it is likely that the impacts of physical and transition risks will be experienced at the same time. This could amplify the economic and financial impacts of climate change due to feedback effects of both types of risks within the financial system, or between the financial system and the real economy. For example, there could be abrupt changes in climate policies, not anticipated by market participants, due to the increased materialization of physical risks. In this scenario, the impact of transition and physical risks could combine, amplifying their effect on financial stability. This is already somewhat evident in Morocco, where authorities raised their climate ambition in the NDC partly due to the increased awareness of the physical impacts of climate change in Morocco.

- There are complex interactions between climate change and other types of risks (e.g., pandemic). There is a need to look at risks holistically (rather than climate as a standalone risk) to understand the interactions with other sectors of the economy and compounding impacts of climate risks with other crises.

- Furthermore, the complex interactions between macroeconomic, financial, and climate impacts are difficult to measure. For example, climate risks could reduce the willingness of firms to provide financial services, further depressing macroeconomic prospects and creating feedback loops that lead to further losses in the financial system.

For the reasons highlighted above, climate impacts on the financial sector could be underestimated due to a wide range of uncertainties. In addition to core, inherent uncertainties in climate science and extreme events modeling, there are significant challenges associated with estimating the economic impacts of climate tipping points (Table 11). Embedding the characteristics of climate risk in macroeconomic and financial risk assessment is challenging and requires models that (i) embed finance and its complexity, (ii) have the capabilities to analyze equilibrium dynamics, (iii) allow conditions of mispricing to occur, and (iv) allow agents to have adaptive expectations about the future.

TABLE 11
Overview of potential complex interactions between climate, macroeconomic, and financial impacts

	**Cumulative effect:** Incremental impacts (e.g., fossil fuel generation) could cumulate over time, leading to "tipping points."
	**Cascading/domino effect:** For example, the COVID-19 outbreak led to a domino effect on supply chains, capital markets, flow of goods, and other aspects of the economy and financial system. Similar domino effects could take place as a result of climate change.
	**Ripple effect:** Climate change could have a ripple effect on other crises (e.g., nature/biodiversity loss). For example, CO_2 can lead to ocean acidification, which could warm oceans and impact coral ecosystems. This could in turn lead to migration of coastal populations.
	**Tipping points:** Climate has many tipping points (e.g., loss of Amazon rainforest or the west Antarctic ice sheet) that could have large, irreversible impacts given the interconnectedness across different biophysical systems.
	**Feedback loops:** Feedback loops could either worsen or strengthen the initial driver. Climate change could lead to various feedback loops (e.g., between macroeconomy and financial system, within the financial system).

Source: IAA Climate Risk Task Force, 2021

SECTION 4

Supervisory and Banking Sector's Response to Climate Risks

4.1 Supervisory and regulatory response to climate risks

BAM has identified the management of climate-related financial risk as a key priority. BAM joined NGFS in 2018 to share and build knowledge on climate risk integration in supervision and central bank operations. In 2019, it established an internal unit dedicated to climate risk and green finance within its banking supervision department. Moreover, BAM's 2020 annual report has included the integration of climate change into the central bank's mission as one of its key goals. During COP26 in November 2021, BAM also announced a series of ambitious plans to address climate risks,[90] including issuing guidelines to the banking sector regarding stress tests and reporting on climate risks, conducting climate risk assessments, and capacity building. However, further work is needed to build up BAM's in-house climate expertise.

BAM has taken steps to define the internal governance structure for climate risk management and ensure that adequate resources are allocated to implement policy actions. In 2019, BAM established an internal unit dedicated to climate risk and green finance within its banking supervision department. The objective of this division is to develop a strategy and supervisory framework for green finance and climate risk management. The division is also responsible for assessing and tracking key climate and environmental risks and deploying preventive or corrective actions to mitigate these risks. However, need for reinforcing internal capacity and of a detailed strategy for climate-related financial risk management remain key challenges for BAM.

In March 2021, BAM issued the directive on the management of climate and environmental financial risks.[91] The directive sets out, at a high level, BAM's expectations to the banking sector on integrating climate and environmental risks into banks' strategies and governance, risk management, training and awareness, and reporting frameworks. The directive requires banks to develop and implement a climate risk strategy and governance framework, risk management practices (including the use of climate scenario and vulnerability assessment analysis), training programs for both employees and clients, and disclosure practices for climate risks. Even though the directive is high level by nature, it provides an important signal to incentivize banks to enhance their management of climate and environmental risks. To date, most countries' supervisory guidance on climate risks has been intentionally high level because many supervisors and financial institutions are still in an early phase of considering these risks.

Building on the high-level directive, BAM is looking to issue more detailed supervisory guidance on climate-related stress testing and scenario analysis.

Over time, BAM intends to move beyond high-level expectations toward setting more prescriptive and detailed expectations in response to climate risks. Building on the high-level directive, BAM is looking to issue more detailed supervisory guidance on climate-related stress testing and scenario analysis. Given the forward-looking nature of climate risks and the inherent uncertainty associated with these risks, scenario analysis and stress testing could be important tools to shed light on the potential impact of severe but plausible climate scenarios that may occur but for which no historical precedent is available. With the support of the World Bank, BAM is in the process of designing microprudential guidelines for banks on stress testing and scenario building, as a follow-up from the recently issued Climate Risk Directive. It is envisioned that the outcomes of banks' stress tests/scenario analyses will be reported to BAM. At this stage, the results are intended to be explorative in nature to inform BAM's understanding of risks faced by the individual banks and to build capacity across the sector, rather than to inform adjustments in capital requirements for banks.

90 BAM (2021), "Individual pledge at COP26 – BAM's engagements to accelerate the greening of the financial sector"
91 Regulatory Directive 5/W/2021

Another priority for BAM is to develop supervisory guidelines on climate-related reporting for banks. This is intended to provide more detailed guidance on how and what data banks need to report in relation to climate risks, in line with the key requirements set out in the directive that was issued in March 2021. The objectives of the supervisory guidelines include to inform the supervisory review process and assess banks' compliance with the directive. Based on guidelines produced in other countries, supervisors often expect financial institutions to disclose information and metrics on climate and environmental risks to which they are exposed, the potential impact of climate risks on the safety and soundness of the institution, and proposed mitigation and management strategies to respond to key climate risks. BAM is looking at international good practice examples such as the work of the International Sustainability Standards Board (ISSB), TCFD and the European Banking Authority to inform the development of the guidelines.

BAM may consider developing more detailed supervisory guidance for banks as a further follow- up to the directive at a later stage. Since 2016, BAM has been tracking the progress of banks' climate risk practices through surveys and consultations. These surveys are intended to inform the scope and structure of follow-up guidance to the directive and BAM's broader supervisory practice. A phased approach is taken to develop the climate risk supervisory framework in order to ensure banks' capacity on the topic could build over time. While the priority is to first focus on supervisory guidelines for stress testing and reporting, BAM has indicated that more detailed supervisory guidelines for other areas, such as governance, strategy, and risk management may also be developed at a later stage. This guidance should be informed by and aligned with the recently finalized BCBS Principles for the effective management and supervision of climate-related financial risks.

4.2 Banking sector practices on climate risk

Stakeholder consultations were carried out through interviews and surveys[92] to better understand Moroccan banks' climate risk management practices. This section provides main findings on the Moroccan banking sector's approach to climate risk across the following areas: strategy and governance, risk management, and disclosure. The section below provides preliminary insights based on the survey results. It should be noted that this has been a snapshot in time. The practices and experience of the Moroccan banks in relation to their management of climate-related risk are continuously evolving and may have progressed since the survey was initially carried out.

4.2.1 Strategy and governance

Almost all banks that responded to the questionnaire believe that climate change presents both risks and opportunities for banks. However, in general banks are at an early stage of integrating climate risks into business models, corporate strategies and governance practices. Most banks have not yet integrated climate considerations into their business model. 36 percent of the surveyed banks have evaluated the impact of climate risks on their business model, and 21 percent have evaluated the long-term impacts of climate risks. There are differences in the level of maturity of Morocco's major banking institutions with regards to the consideration of climate risk. The banks that have been relatively more active on the climate agenda are mostly driven by international initiatives (e.g., Equator Principles, United Nations Environment Program Finance Initiative), or have parent companies that are based internationally (e.g., European countries). Banks often consider climate risk within broader sustainability or even corporate social responsibility (CSR) frameworks. The primary focus for most institutions seems to be on the reputational side, and less on the view of climate risk as a financial risk.

While most banks are still in the early stages of evaluating the impact of climate risks, steps have been taken to integrate climate risks into banks' broader governance frameworks. 71 percent of banks reported that they have board responsibility for climate-related risks, and 50 percent of banks have already (fully or partially) developed a strategy that includes climate risks. Banks have established various committees to inform the board about climate risks, although these committees vary in nature. For example, some of the committees fall under the remit of CSR, while others established risk management or sustainable development committees.

At the same time, several institutions indicated that they are deploying more staff resources toward climate risk (or sustainability more broadly). This is an encouraging sign that climate change is being more firmly embedded into the business model. Good practices highlighted by banks included the introduction of training programs to raise awareness of climate risks among staff, as well as integrating climate risks into existing roles and responsibilities of individuals.

92 This survey was carried out in July 2021; 14 banks were surveyed in total. Note that some banks may have progressed in the development of their approach to managing climate risk since the survey was carried out.

4.2.2 **Risk management**

Some banks have started integrating climate change into their risk management framework. 31 percent of sampled banks have included climate change in their risk appetite statement. Furthermore, in many cases, climate risk is covered as part of the bank's CSR agenda, instead of its core operations. Few banks have introduced specific targets, tools, or metrics to assess climate risks. For example, 36 percent of sampled banks have measured their carbon footprint or taken steps to assess the extent to which their portfolio is aligned with the Paris Agreement. Some of the key challenges for banks to fully integrate climate into their risk management framework include the need for standardized tools, data, or metrics for climate risk; uncertainties around the nonlinear impacts of climate change, particularly in the longer-term horizon; need for matter expertise; and need for resources.

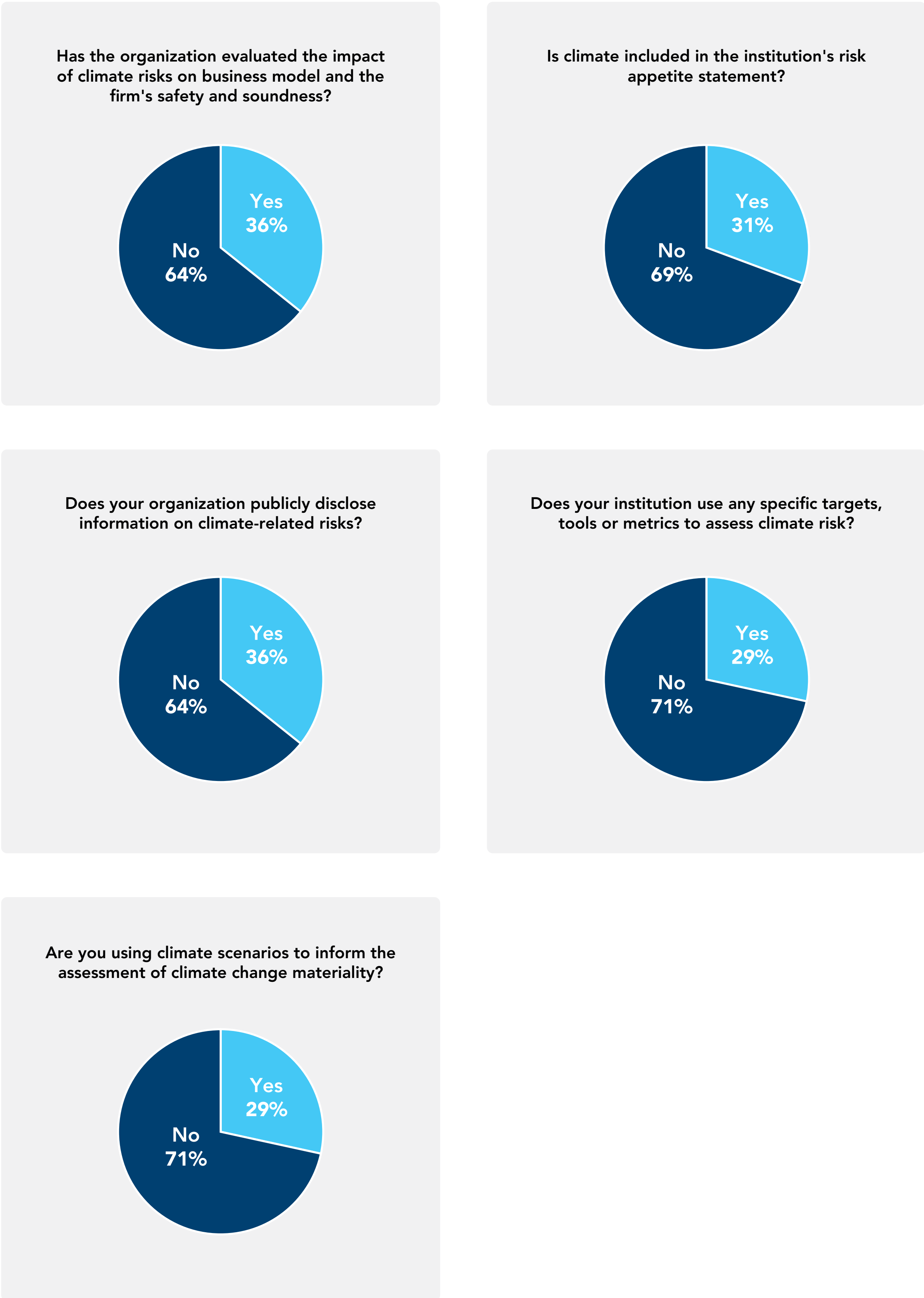
21 percent of the surveyed banks have conducted a scenario analysis/vulnerability assessment to analyze climate risks. Data limitation was identified as one of the key challenges, especially in terms of granularity. Other challenges include the need for standardized and approved methodologies to assess and manage climate risks. Overall, physical risk seems to be more of a concern for banks than transition risk. In particular, drought risk was identified as a key concern, with impacts already being observed in the agricultural sector. There is also significant literature available to assess the impact of droughts in Morocco, considering the country's experience with this type of hazard. On the other hand, flood risk is much less anticipated by banks. This is likely due to a combination of a lack of data on this risk and lower general risk awareness resulting from the lower incidence and significance of the risk to the country.

4.2.3 **Disclosure**

Progress on climate risk financial disclosure is at an early stage. 36 percent of banks have disclosed, internally or publicly, information on climate risks. Furthermore, 29 percent of banks consider climate risk under Pillar 3 disclosure or other existing disclosure requirements. However, 50 percent of banks have plans, or are taking steps, to deliver TCFD-aligned disclosures.

Banks are calling for more guidance, data, and capacity building to help them manage climate risks. It was suggested by banks that BAM could provide further guidance in response to climate risks (e.g., for scenario analysis/stress testing, governance, risk management, disclosure); provide data, proxies, tools, or case studies that could be leveraged for the banks' climate risk analyses; conduct training sessions; and take steps to ensure a leveled playing field in the transition toward low carbon. Banks also suggested that international standard-setting bodies could help by delivering clear, harmonized guidelines and definitions on how banks could manage climate risks, while ensuring that these international guidelines are applicable to the EMDE context. It was also recommended that standard-setting bodies could facilitate capacity building and outreach sessions to share lessons and international good practices. Since the survey, BAM has signed a Memorandum of Understanding with the European Bank for Reconstruction and Development to provide technical assistance to banks and help them advance in the implementation of Regulatory Directive 5/W/2021. BAM continues to consider using international expertise to help banks better understand and leverage international tools. This includes, for example, a session on portfolio alignment methodologies that was held with the banking sector.

FIGURE 29
Summary of survey response



SECTION 5

Concluding Remarks and Proposed Next Steps

The banking sector in Morocco could be increasingly vulnerable to climate transition and physical risks. While the impact of climate change may not be systemic across the financial system, climate impacts could vary widely across banks, with several banks expected to be highly vulnerable to the impacts of these risks. Furthermore, the impact of climate risks on the banking sector could be largely underestimated due to the need for data and the inability to account for the complex interlinkages between climate, financial, social, and macroeconomic impacts. The report's findings should therefore be interpreted with caution, given the complexities of estimating future climate impacts and evolving assessment approaches. Based on the report's findings, a range of policy recommendations has been identified to further support the assessment and management of climate-related financial risks for the banking sector, which are discussed below.

Policy recommendations

Moving forward, BAM should aim to continuously improve its understanding and management of climate-related financial risks. This may involve updating the risk analysis as needed and conducting a more in-depth exercise with the banking sector. This could be part of a supervisory stress test in the context of the broader updates to BAM's stress testing framework. To enhance and expand on the risk analysis, it will be important to improve the quality and granularity of the data that is available to conduct the risk assessment. This will require engaging with the banking sector to improve their data capabilities and to encourage them to liaise with clients to obtain the necessary data. BAM's work on developing guidance on the climate-related reporting will be a key component feeding into this. This could also help with developing indicators to monitor key climate risks, both at the institutional and systemic level. Continued focus on building institutional capacity will support the periodic review and management of the key climate risks identified.

Future risk analysis work could consider improving the scenarios and modeling, for example, by exploring additional transmission channels to the economy and banking sector. For example, the quantitative drought analysis presented in this report focused primarily on the impacts of drought on the agricultural and agriculture-related sectors. Future work could attempt to quantify the impacts of drought on other sectors, and via other transmission pathways, with extreme drought events potentially directly and indirectly affecting a wide range of sectors (as outlined in Box 2). Future quantitative analysis of physical climate shocks could also consider improvements to the suite of scenarios (e.g., exploring potential compounding and cascading scenarios); the hazard, exposure, and vulnerability data used in the catastrophe modeling (e.g., improving the granularity of the modeling and conducting additional calibration and validation of vulnerability data); improvements to the modeling of the indirect impacts of events (e.g., leveraging approaches that assess the impacts of damages to critical infrastructure); as well as improvements to the macroeconomic and financial impact modeling (e.g., by further exploring the assumptions, uncertainties, and limitations of the models).

To enhance and expand on the risk analysis, it will be important to improve the quality and granularity of the data that is available to conduct the risk assessment.

Building on this initial climate risk analysis, BAM could assess whether the central bank's macro- and microprudential monitoring and assessment framework needs to be updated to structurally embed the consideration of climate-related and environmental risks. Developing an internal roadmap to integrate the consideration of climate-related risks into micro- and macroprudential supervision can be an important tool in defining the forward-looking priorities, engaging the relevant internal stakeholders, and supporting a coordinated approach across the organization. This could include the introduction of standard vulnerability assessments or stress tests over time. BAM has started the integration of climate risks into day-to-day supervisory practice, including in supervisory tools, methods, and scoring systems for on- and offsite supervision. This implies the integration of climatic considerations into BAM's Supervisory Review and Evaluation Process (SREP) and in the ICAAP reports. At a later stage, this may also involve integrating climate considerations into the fit-and-proper testing framework.

Developing additional supervisory guidance on climate-related and environmental risks can support enhancing the banking sector's response to managing these risks. Supported by the World Bank, BAM is developing more detailed regulatory guidance to help banks conduct a climate risk stress test and implement a reporting framework on climate risks. At a later stage, it would be good to consider developing more detailed climate risk supervisory guidance in other areas (including governance and risk management), building on Regulatory Directive 5/W/2021. This will also allow the banking sector to develop harmonized and more in-depth approaches to managing these risks. In addition, BAM could consider introducing climate-related disclosure requirements. Considering the importance of enhancing market transparency, this will support financial sector participants in adequately identifying climate-related risks and opportunities. Such disclosure requirements could be part of Pillar 3 guidance on climate-related and environmental disclosures or consist of national regulations on such disclosures, implemented by regulators that include both financial sector and real economy firms.

Supported by The World Bank, BAM is developing more detailed regulatory guidance to help banks conduct a climate risk stress test and implement a reporting framework on climate risks.

As the supervisory approach develops, BAM could consider thematic reviews or on-site supervision for highly exposed entities. The climate risk analysis presented in this report has highlighted that the implications from climate change are relevant to the Moroccan banking sector and may exacerbate over time. To obtain a more in-depth view of the banking sector's climate risk practices, BAM could consider conducting a thematic supervisory review.

BAM could participate in the policy dialogue on how to stimulate the development of private insurance markets and/or public schemes to transfer climate and disaster risks. Transferring climate and disaster risks to those who have the most capacity to bear the risks, including global reinsurers, could support banks in providing loans to vulnerable areas, while still managing risks appropriately. For further discussion of the insurance and disaster risk finance, see Box 4.

Policymakers and BAM should seek to address critical data gaps that limit authorities' and financial institutions' ability to measure climate risk exposures and run climate-related financial stress tests. For example, key data gaps include the lack of granular and robust financial exposure data at the geographical and sectoral level as well as the lack of granular data on emission intensity and absolute emissions by sector. To address these data gaps, BAM may have to develop additional disclosure and reporting requirements for banks. Policymakers other than BAM may also have to take policy actions. For example, a comprehensive green taxonomy and disclosure requirement for real sector companies (in addition to financial institutions) may also be needed to further enhance market transparency. Based on its role in the financial sector, BAM could play a convening and catalyzing role for these actions and developments, providing analytical inputs and bringing stakeholders around the table.

Forward-looking guidance on climate and environmental policies can support longer-term decision-making and risk management practices. Relevant policymakers and BAM are encouraged to work together to provide the banking sector with credible and long-term guidance on relevant economywide or sector-specific policies on climate mitigation, adaptation, and broader environmental goals. This will allow the sector to incorporate such forward-looking guidance into investment and lending decisions, as well as factor this into their risk management decisions.

Policies and actions can also be taken to stimulate green finance and enhance financial protection against climate risks. As shown in Box 4, Morocco has already taken important steps to stimulate green finance, although green bonds and other green finance markets remain small. Moving forward, policymakers could consider developing a national green taxonomy to provide a harmonized framework for defining environmentally sustainable economic activities. Various measures could also be taken to encourage the uptake of the labeled bond market, as detailed in Box 4. At the same time, as shown in Box 5, several measures can be taken to enhance financial protection against climate and disaster risks. This includes scaling up existing disaster risk financing and insurance tools, including the domestic private insurance market, as well as sovereign and market-based risk transfer solutions (e.g., reinsurance and CAT bonds). The government could also strengthen its management of disaster risks by ensuring that all investments associated with climate adaptation and resilience are closely aligned with the country's disaster risk management strategy, NDC, and other relevant strategic frameworks.

BOX 4

Policies and actions to stimulate green finance in Morocco[93]

Financing for climate action has remained limited and largely focused on mitigation measures. Given Morocco's growing climate ambition, the low-carbon, climate-resilient transition could present an important investment and growth opportunity for financial institutions. Nonetheless, a recent evaluation[94] estimates that Morocco invested an average of 1.5 percent of GDP per year (eq. 14 billion dirhams per year) on climate action between 2011 and 2018, with only a moderately upward trend.[95] The majority of this financing went toward climate mitigation projects in the energy and transport sectors. While financing for climate action has increased over 2011–2018, the total financing falls far short of the funding needs to meet Morocco's climate ambition, particularly in the context of climate adaptation.[96]

Moroccan authorities have taken important steps to establish a framework and strategy for greening the financial system, but a detailed green finance roadmap has yet to be developed.[97] Since 2016, Moroccan authorities have taken several steps to green the financial sector. Key milestones include developing a broad roadmap to align financial institutions and capital markets with sustainable development goals, the introduction of disclosure and reporting standards, and the adoption of key reforms to stimulate the creation of a corporate green bond market (Figure 30). Nonetheless, financial institutions' climate investments remain limited, and green finance markets in Morocco remain relatively small.

93 These considerations are based on World Bank (2022), Morocco Country Climate and Development Report.
94 Based on the results of the review Panorama of the Financing of Climate Action in Morocco 2011-2018, carried by the Caisse de Dépôt et de Gestion (CDG) and the Institute for Climate Economics (I4CE).
95 Note that given the absence of climate-sensitive tagging on the public side and lack of a green taxonomy on the private side, computing Morocco's total mitigation and adaptation investments is challenging, and reported numbers likely underestimate the overall effort.
96 About 5.3 percent annual increase.
97 To assess progress and identify the gaps that still need to be filled, the recent framework developed by the World Bank, Toolkits for Policymakers to Green the Financial System, was applied, producing a preliminary policy benchmarking assessment that has been informed by consultations with key policymakers and stakeholders. See more detailed information in background note on "Greening the Financial System in Morocco."

FIGURE 30
Greening the Moroccan financial system: Key milestones

2016-2017

- Roadmap for aligning the financial sector with sustainable development
- AMMC and CSE issue CSR and ESG Guidelines
- AMMC issues Green Bonds Guidelines

2018

- AMMC published amended listing rules & Green, Social and Sustainability Bonds Guidelines

2019

- BAM launches new unit dedicated to green finance
- BAM publicly supports TCFD standards
- AMMC issues mandatory ESG reporting requirements

2021

- BAM publishes the Regulatory Directive on climate and environmental financial risk management
- BAM initiaties climate risk assessment and stress test
- Gender Bond Guidelines

Moving forward, a national green taxonomy could provide a standardized classification system to define what constitutes a "green" economic activity. The lack of a taxonomy continues to be a constraint, as it limits financial institutions' ability to make informed decision on green investments. It also reduces the reliability and comparability of disclosures and green finance products.

Additional steps could be taken by authorities to stimulate and ensure the integrity of green bonds and other green finance markets. Between 2016 and 2018, the Moroccan Capital Market Authority (AMMC) produced guidelines describing the principles and actions needed to issue a green bond, including the use of proceeds as well as evaluation and selection of eligible projects. However, the uptake of green bonds remains very limited in Morocco. To date, only five green bonds have been issued, with all the issuances taking place between 2016 and 2018, when the guidelines were first introduced. The total outstanding value of green bonds in Morocco as of 2020 amounted to around $400 million,[98] which have been issued by banks, corporates, and state-owned enterprises. No sovereign green bond has yet been issued by the central government.[99] There are several ways in which authorities could stimulate demand for green bonds. For example, the government could issue a sovereign green bond to raise the profile of the market to potential investors and issuers. Based on other countries' experiences, authorities could also reduce the listing fees for corporate green bonds, subsidize second party verification costs, and design appropriate tax incentives. In parallel to setting up incentives, authorities should also take steps to ensure the integrity of green bond markets. This may include, for example, (i) enhancing disclosure and reporting requirements for green bonds; (ii) developing the information infrastructure to enhance market transparency; (iii) setting expectations for second opinion providers; and (iv) developing mechanisms to prevent, detect, and sanction the misuse of funds. Similar steps could be taken to stimulate green finance instruments other than green bonds, such as green loans or more novel instruments such as sustainability-linked bonds and loans.

98 This is still a relatively low figure, especially if compared with the total volume of outstanding Moroccan corporate debt, which stood at more than US$33.4 billion at the end of October 2020.

99 The five institutions that have issued green bonds so far in Morocco are the National Sustainable Energy Agency MASEN (MAD 1.15 billion, 18 year, 10 bp risk premium); BMACE Bank of Africa (MAD 500 million, five years, 55–65 risk premium), Banque Centrale Populaire (EUR 135 million, 10 years, 175 risk premium); Casablanca Finance City Authority (MAD 355 million); Al Omrane Holding (MAD 1 billion, 10 years, 100–120 bp risk premium). These figures only encompass bonds that are "climate-green" as defined by the CBI and in compliance with the regulator's guidelines, thereby excluding self-labeled green bonds or other types of sustainable bonds from corporates.

BOX 5

Policies and actions to scale up climate adaptation and resilience measures

Concurrent to these actions, the government of Morocco is planning to pursue efforts to improve its disaster and climate-related risk management by scaling up its financial protection and strengthening adaptation and risk reduction measures. In the past 20 years, the government has embarked on an ambitious reform agenda aimed at improving its disaster and climate-related risk management with several major milestones related to ex-ante risk reduction, preparedness, and financing (e.g., Law 110-14; adoption of DRM and Disaster Risk Financing and Insurance strategies; the development of a Flood Risk Management Information System within the Ministry of Interior).

The government could further strengthen the financial resilience of the Moroccan economy and population by scaling up existing Disaster Risk Financing and Insurance tools. This can be achieved by expanding the scope of hazards covered (e.g., integrate the loss of income that a business suffers due to business interruption after a disaster), the populations (e.g., small farmers), and assets targeted (e.g., public infrastructure) by its Disaster Risk Financing and Insurance Strategy. The development of the domestic private insurance market and the expansion of the range of available sovereign and market-based risk transfer solutions (e.g., reinsurance and CAT bonds) could also help better protect vulnerable populations and the economy against climate risks and disasters. The government could also consider CAT risk sharing arrangements to help de-risk existing credit guarantee schemes (CGS) against climate and disaster risks in order to leverage the economic capital needed to support the CGSs' activities (reimburse banks for the CGSs' share in the CAT losses of their current portfolio) and to allow them to guarantee new loans to firms affected by disasters. Such CAT products would also limit the fiscal exposure of the government by leveraging private capital and reinsurance markets.

The government could further strengthen its disaster risk management by ensuring all climate adaptation and DRM investments are closely aligned with and contribute to the operationalization of the national DRM strategy, the NDC, the National Plan against Floods, the local urban resilience strategies and climate action plans, and other strategic DRM-related frameworks.

Considerations for the banking sector

Moroccan banks should continue building capacity to assess and manage climate-related financial risks. Banks are expected to build capacity to ensure compliance with BAM's directive on climate and environmental risk management. Over time, banks should also work toward aligning their climate risk management frameworks with global guidance and international good practice, including the BCBS's Principles on the effective management and supervision of climate-related financial risks and emerging climate-related disclosure guidance from the ISSB. Aspects of climate risk management that banks should focus on may include the following: (i) developing clearly defined governance structures and business strategies for climate risk management; (ii) integrating material climate risks in banks' risk management frameworks and risk appetite statements, including by establishing internal control frameworks and conducting climate risk vulnerability analysis; and (iii) enhancing climate risk disclosure. In addition, banks should work on enhancing their internal data environment to support the internal assessment of climate-related risks as well as supervisory-driven climate risk assessments. This includes improving data quality, granularity, and availability where needed through engaging with counterparties.

Annex

Annex I: **Catastrophe modeling methodology**

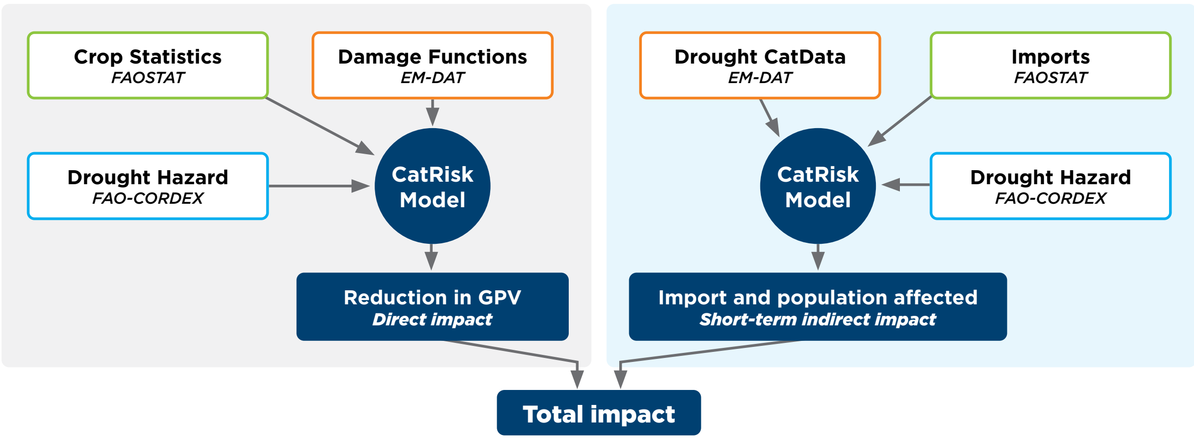
a) Catastrophe modeling methodology for drought

The methodology of the drought catastrophe model, which differentiates between the computation of direct and short-term indirect impacts, is outlined in Figure 31. It is based on regression analysis of the country based on ex-post hazard and exposure data, thus providing results aggregated at the country level.

FIGURE 31

Drought catastrophe model description

The hazard component is outlined in blue, exposure in green, and vulnerability in orange.



The hazard component of the model (outlined in blue in Figure 31) uses a combination of (i) indices to characterize drought intensity, namely the Agriculture Stress Index (ASI) and Vegetation Health Index (VHI),[100] and (ii) an index to characterize drought duration, namely the Consecutive Dry Days index (CDD),[101] calculated using historical climate data from CORDEX-MENA. The probability of occurrence of events of particular intensity and severity is then characterized using a statistical analysis of historical ASI, VHI, and CDD data for the period 1984–2019.

The exposure component of the model (outlined in green in Figure 31) uses country-level yearly tabular data from FAOSTAT to identify, for the most relevant crops, coverage (in ha), production (in tonnes), and gross production value (GPV, in USD). Data is extracted for crops identified as a major source of concern in Morocco based on a literature review for past events,[102] namely wheat, barley, potatoes, citrus, olives, and other crops. Crops are differentiated into two classes: (i) **small farms** with low adaptive capacity, low access to water resources, and growing low value crops (mainly wheat and barley); and (ii) **large farms** with higher adaptive

100 ASI and VHI are provided in the form of maps on a yearly basis by the FAO through its web-platform Global Information and Early Warning System (GIEWS); FAO-GIEWS, http://www.fao.org/giews/earthobservation/

101 The computation of CDD is performed using Climate Data Operators (CDO; Schulzweida 2019), using data from CORDEX-MENA.

102 The literature review for past events based on several papers (El Khatri and El Hairech 2014; RMSI 2012; World Bank 2018; FAO 2018; World Bank 2013) identified wheat and barley as being the major crops of concern. Wheat is the crop with historically the highest area coverage, highest production value, and highest GPV, while barley is second in area coverage and third in production and GPV. Both crops are common along the central area of Morocco, being usually rain-fed. Other relevant corps are potatoes, in Northwest Morocco, characterized by small-holders farms (Blom-Zandstra et al., 2020); citrus, grown mainly in the northern part of the country by large-scale farmers (El Hari et al. 2010; World Bank 2018); and olives, grown both by small- and large-scale farmers (World Bank 2018); RMSI (2012), Morocco Natural Hazards Probabilistic Risk Analysis and National Strategy Development Drought Hazard Report. Department of Economic and General Affairs, Kingdom of Morocco; World Bank (2018), Climate Variability, Drought, and Drought Management in Morocco's Agricultural Sector; FAO (2018), Drought Characteristics and Management in North Africa and the Near East; World Bank (2013), Morocco Natural Hazards Probabilistic Risk Analysis; Blom-Zandstra, G.,Bouwma, I., Verzandvoort, S. (2020). The Potato Value Chain in Morocco. Wageningen Research; El Hari, A., Chaik, M., Lekouch, N., Sedki, A., Lahrouni, A. (2010), Water Needs in Citrus Fruit in a Dry Region of Morocco. Journal of Agriculture and Environment for International Development 104(3–4), pp. 91–99.

capacity, decent access to water resources (including irrigation), and growing more valuable crops, such as citrus.

The vulnerability component of the model (outlined in orange in Figure 31) utilizes a regression analysis to develop direct damage functions that relate to drought intensity and reduction in crop GPV. The analysis uses historical data for drought events, taking the closest nondrought year before each event as a baseline from which the reduction is calculated. The analysis is completed for each of the main crops of concern. Small farms are assumed to have low coping capacity, with the highest level of impacts starting from the first year of a drought event. Large farms are assumed to have a higher coping capacity, with some adverse effects contained during the early years of the drought and highest impact levels only realized in later years. To capture this effect, reduction factors are applied to the impacts to large farms in case of a multiyear event. These reduction factors are estimated through an analysis of the temporal evolution of drought impacts on high value crops relative to low value crops for historical events.

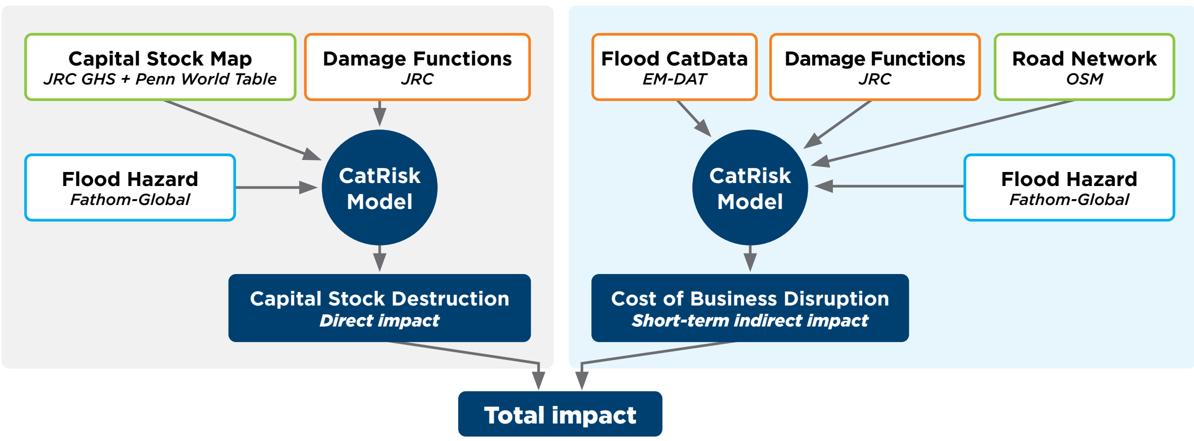
Direct impacts for a specific scenario are assessed by applying the drought direct damage curves to the exposed crops.

Short-term indirect impacts include (i) increased trade import of cereals due to lower internal production and (ii) impacts on agricultural population (population affected and job loss). Increased import of cereals is modeled based on a regression analysis of drought intensity versus import increases for barley and wheat, based on historical data from FAOSTAT. Impacts on agricultural population are estimated as the combination of (i) the number of people affected (estimated by scaling the drought direct damage function using data for number of people affected from the EM-DAT catalog) and (ii) the number of jobs lost in the agricultural sector (estimated by assuming a linear relationship between the number of people affected and the number of jobs lost, with a conversion factor estimated from reports of job losses during the 2015–2016 drought event).[103]

b) Catastrophe modeling methodology for flood

The methodology of the flood catastrophe model, which differentiates between the computation of direct and short-term indirect impacts, is outlined in Figure 32.

FIGURE 32
Flood catastrophe model description
The hazard component is outlined in blue, exposure in green, and vulnerability in orange.



103 In the literature, we found that for the drought event of 2015–2016, 175,000 people lost their jobs in the agricultural sector due to the severe drought (175,000 Lose Their Jobs Due to Drought in Morocco. Middle East Monitor [MEMO], August 8, 2016, https://www.middleeastmonitor.com/20160808-175000-lose-their-jobs-due-to-drought-in-morocco/).

The hazard component of the model (outlined in blue in Figure 32) utilizes Fathom-Global probabilistic flood hazard data,[104] which comprises riverine[105] and pluvial flood maps (extent and depth) at a horizontal resolution of about 90 meters for 10 standard RPs. The hazard component is the same for both direct and short-term indirect impacts.

The exposure component of the model is outlined in green in Figure 32. The exposure data used to estimate **direct impacts** consists of a map of capital stock, which is computed by spatially disaggregating PWT[106] national capital stock data. The spatial disaggregation utilizes the Global Human Settlement Layer–Population (GHS_POP)[107] and the Settlement Model Grid (GHS_SMOD),[108] which provide population and built-up area densities. The rationale is that capital stock (e.g., machinery and equipment) is more likely to be in populated or built-up areas. The maximum of the two normalized GHS_POP and GHS_SMOD densities per pixel is used to estimate capital stock density. The capital stock density map is then classified into two sectors using agriculture (including pasture) and industry/services (urban) land cover classes identified from the Copernicus Global Land Service Land Cover data set.[109] Finally, the capital stock data is distributed by means of its density. The exposure data used to estimate **indirect impacts** consists of a road network map from Open Street Map.[110]

The vulnerability component of the model (outlined in orange in Figure 32) uses depth-damage curves per sector (agriculture, services/industry, transportation) derived from the JRC global depth-damage curves database.[111]

Direct impacts are assessed by applying the depth-damage curves to the exposed elements resulting from the overlapping of the hazard map with the exposure map.

Short-term indirect impacts comprise capital flow interruption and impacts on labor productivity, which depend on the duration of the flood events. The duration of flood events per each probability of occurrence is estimated from historical flood data taken from the EM-DAT database.[112] The impact due to **capital flow interruption** is computed by multiplying national annual GDP by the direct damages to the transportation network as a proportion of the overall transportation network (proxy of magnitude of the shock) and the duration of the flood event as a proportion of the year (proxy of duration of the shock), based on a method adapted from Carrera and colleagues.[113] Finally, the impact on **labor productivity** is estimated by using the duration of flood events and the number of people affected by the hazard (based on past flood events in the EM-DAT catalog).

104 Fathom-Global, https://www.fathom.global/
105 The "defended" version of the maps were used in our analysis. Defended flood maps in Fathom-Global assume that urban centers contain a certain degree of structural flood defenses, thus reducing the intensity of flood hazard in those areas.
106 PWT, https://www.rug.nl/ggdc/productivity/pwt/
107 GHS_POP, https://ghsl.jrc.ec.europa.eu/ghs_pop.php
108 GHS_SMOD, https://ghsl.jrc.ec.europa.eu/ghs_smod.php
109 CGLS LC, https://land.copernicus.eu/global/products/lc
110 OSM, https://www.openstreetmap.org/
111 Huizinga et al. (2017).
112 Guha-Sapir, D., Below, R., Hoyois, P. (2009), EM-DAT: The CRED/OFDA International Disaster Database, www.emdat.be
113 Carrera, L., Standardi, G., Bosello, F., Mysiak, J. (2015), Assessing Direct and Indirect Economic Impacts of a Flood Event through the Integration of Spatial and Computable General Equilibrium Modelling. Environ Model Softw 63, pp. 109–122. doi:10.1016/j.envsoft.2014.09.016

c) Catastrophe modeling methodology for future climate conditions

Scenarios under climate change conditions have been modeled by adapting the catastrophe models used for the current climate. The adjustment is applied to the hazard component of the catastrophe model; no changes are applied to the exposure (e.g., due to future population and economic growth). The hazard adjustments are calculated based on changes in extreme climate indices (Table 12). These indices under current climate conditions (used in the baseline catastrophe modeling) are compared with projections of the indices under future climate conditions (i.e., RCP 4.5 and RCP 8.5 for 2030 and 2050) at a country level using data from CORDEX-MENA.[114] By linking each scenario to the extreme climate indices, and by knowing how these indices are going to change in the future due to climate change, we are able to estimate the frequency of the current climate scenarios under future climate conditions (e.g., an RP50 flood in the current climate might become an RP20 flood in the 2050 climate).

For the drought climate scenarios, MOSAICC[115] data was used to stress the damage functions to incorporate the effects of climate change, enabling the evaluation of yield variation of crops.

TABLE 12

Extreme climate indices used to estimate changes in frequency and intensity of floods and droughts

Index	Name	Description	Peril
Rx1day	Maximum one-day precipitation	The maximum one-day value for period j are Rx1dayj = max (RRij), where RRij is the daily precipitation amount on day i.	Flood
Rx5day	Maximum consecutive five-day precipitation	Then maximum five-day values for period j are Rx5dayj = max (RRkj), where RRkj is the precipitation amount for the five-day interval k.	
CDD	Consecutive dry days	Maximum length of dry spell (i.e., maximum number of consecutive days with RRi < 1mm).	Drought
SPEI	Standardized Precipitation Evapotranspiration Index	SPEI considers both precipitation and temperature data to account for the effect of evapotranspiration on drought development through a basic water balance calculation.	

114 https://cordex.org/domains/cordexregion-mena-cordex/
115 https://www.fao.org/in-action/mosaicc/en/

Annex II: **Macroeconomic modeling and assessment of total economic impacts**

Model description

To assess the macroeconomic and financial impacts of natural hazards in Morocco, an EIRIN behavioral model has been developed. The EIRIN model is a stock-flow consistent model of an open economy composed of heterogeneous agents and sectors represented as a network of interconnected balance sheet items. In the EIRIN model, agents and sectors interact with each other and with the foreign sector through a set of markets: (i) government bonds and stock shares market, (ii) credit market, (iii) consumption goods market, (iv) labor market, (v) energy market, (vi) tourism market, (vii) capital goods market, and (viii) raw materials market. The formation of demand, supply, and prices in each market is independent of each other at any simulation step.

The EIRIN model builds on recent related macromodeling literature and allows researchers to trace a direct correspondence between stocks and flows and displays the dynamic relations of agents and sectors' balance sheets.[116,117] In turn, it is important to analyze (i) the impact of a shock on individual agents and sectors of the economy (at the level of balance sheet entry), (ii) the impact of a shock on macroeconomic variables (e.g., GDP, unemployment, interest rate) and financial risk variables (e.g., banks' PD and NPL), and (iii) the drivers of reinforcing feedbacks that generate in the financial sector and that could amplify the original shocks, leading to cascading economic losses.

As a difference from traditional macroeconomic models (e.g., Dynamic Stochastic General Equilibrium models), the EIRIN model relaxes strong assumptions on agents' perfect foresight and efficient markets hypothesis that may not hold in the context of deep uncertainty, nonlinearity, and endogeneity of climate risks.[118] It considers the heuristics and behavioral patterns of sectors that contribute to the generation of emerging phenomena and out-of-equilibrium states of the economy. Another significant difference is that the EIRIN model endogenizes the financial sector and the financial GV market, which is crucial to assessing the double materiality[119] of climate-related financial risks.[120]

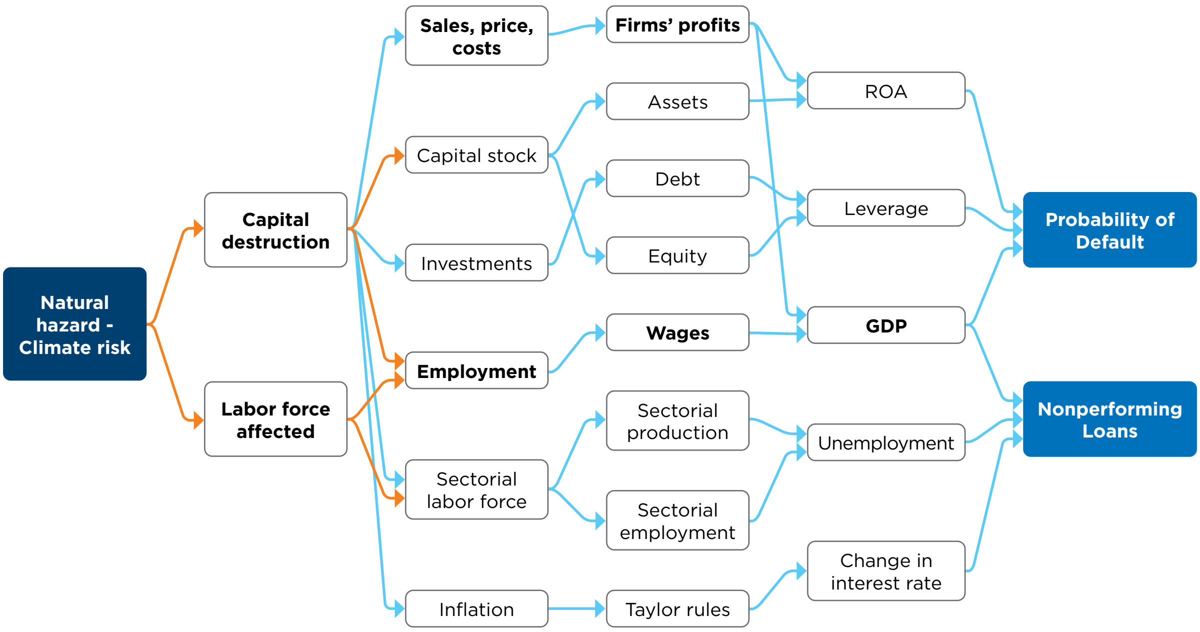
While the input shocks conditioned to the scenarios exogenously impact the model, the indirect impacts are produced in the EIRIN model by the endogenous reactions of the sectoral and macroeconomic variables over time, driven by sectors and agents' interactions. Direct impacts and short-term indirect impacts vary with the considered hazard. Drought directly impacts capital stock, gross value added (GVA), and population of the agricultural sector, and flood directly impacts capital stock and population in all sectors of activity exposed to flood, including agriculture, service, and the industry sector. Long-term indirect impacts are estimated using computational experiments performed with the EIRIN model, reproducing in a realistic way the risk transmission channels and connecting the sectors affected by the direct impacts with the other sectors and with the rest of the economy. In this regard, the EIRIN model captures

116 Dunz et al. (2021), "Macroeconomic and Financial Impacts of Compounding Pandemics and Climate Risks"
117 Monasterolo and Raberto (2018), "The EIRIN flow-of-funds behavioural model of green fiscal policies and green sovereign bonds"
118 Monasterolo (2020), "Climate change and the financial system"
119 EIRIN model endogenizes the financial sector and the financial market, which allows analyzing, on the one hand, how climate change and policies impact financial stability via changes in firms' profitability and households' economic conditions, and on the other hand, it allows us to analyze how financial policies and financial actors' consideration of climate risks affect firms' response (e.g., in the case of banks, the revision of interest rate and exposed firms, or in the case of insurance firms, the cost of insurance products) via a change in the cost of capital and the implications on macroeconomic dynamics (e.g., employment, GDP, governments' tax revenues, etc.).
120 Gourdel et al. (2021), "Assessing the double materiality of climate risks in the EU economy and banking sector"

how nonlinearities and indirect impacts can emerge through endogenous feedback mechanisms driven by the behavior of the agents and sectors of the economy and finance and their interaction.

To capture the impact of climate disasters on the financial sector, the EIRIN model considers three financial risk metrics and their modeling solutions: (i) PD, (ii) NPLs, and (iii) CAR. The change over time of these metrics is completely endogenous in the model and dependent on the shock scenario, as predictor variables are endogenously evolving within the simulations. The variables through which a natural hazard shock impacts a financial risk metric include (i) the determinants of each metric and (ii) the sectoral and macrofinancial variables that affect the determinant. As indicated in the figure below, the determinants for PD considered in this analysis are ROA, leverage ratio, and GDP. For NPLs, the determinants are changes in interest rate, unemployment, and GDP. For both metrics, the destruction in capital stock translates into lower sectors' production and thus lower revenues and employment. This leads to an increase in sectoral PD and NPLs since their determinants are affected.

FIGURE 33
Natural hazard transmission channels to PD and NPLs

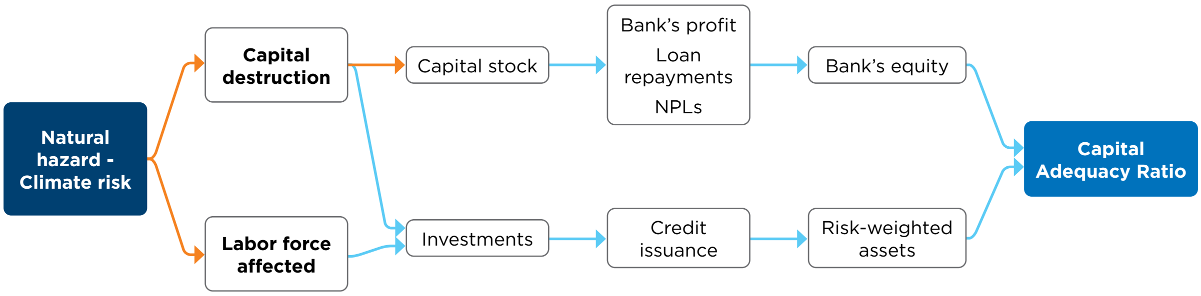


The orange arrows indicate the direct impacts, while the blue arrows correspond to indirect and endogenous impacts. **Variables in bold** represent the common items with respect to the PD and NPLs variation. Source: Authors' own elaboration.

Source: Essenfelder, A.H., Mazzocchetti, A., Monasterolo, I. (2021) "Compound risk assessment for DRF: focus on climate physical risks and the banking sector – Methodological note". Authors' own elaboration.

For the CAR parameter, the EIRIN model considers banks' equity and risk-weighted assets as the main determinants (Figure 34). The higher (lower) the CAR parameter, the more (less) equity is required to issue new loans.

FIGURE 34
Natural hazard transmission channels to CAR



The **orange arrows** indicate the direct impacts, while the **blue arrows** correspond to indirect and endogenous impacts. **Variables in bold** represent the common items with respect to the PD and NPLs variation. Source: Authors' own elaboration.

Source: Essenfelder, A.H., Mazzocchetti, A., Monasterolo, I. (2021) "Compound risk assessment for DRF: focus on climate physical risks and the banking sector – Methodological note". Authors' own elaboration.

Annex III: **1-in-50-year drought and pluvial flood results under historical climate conditions**

This annex presents the modeling results for 1-in-50-year scenarios for drought and pluvial flood. These results highlight the potential macroeconomic impacts for these less severe scenarios compared with the results for the 1-in-500-year scenarios presented in the main body of this report.

For drought, the macroeconomic impacts are less pronounced but still considerable for the 1-in-50-year scenario compared with the 1-in-500-year scenario, as highlighted in Table 13. The GDP shock, increase in unemployment, and increase in public deficit do not reach the same levels for the 1-in-50-year drought scenario as in the case of the 1-in-500-year drought scenario but are nonetheless not insignificant. The relative impacts on the modeled indicators of the 1-in-50-year scenario are approximately half those of the 1-in-500-year scenario. For example, the GDP loss reaches a maximum of 0.88% at the end of the modeled shock period for the 1-in-50-year event, compared with 1.81% for the 1-in-500-year event.

TABLE 13
Summary of the impact of 1-in-50-year drought on macroeconomic variables by year under historical climate conditions

Variable	Year 1	Year 2	Year 3	Year 4	Year 5
GDP (loss %)	(0%)	(0.13%)	(0.34%)	(0.61%)	(0.88 %)
Consumption (loss in %)	(0%)	(0.39%)	(1.28%)	(2.11%)	(2.39%)
Unemployment rate (absolute)	9.7%	9.85%	10%	10.15%	9.98%
(difference with BAU)	0%	+0.2%	+0.46%	+0.74%	+0.60%
Public deficit (% of GDP)	3.57%	3.67%	3.77%	3.81%	3.66%
(difference with BAU)	0%	+0.12%	+0.27%	+0.38%	+0.27%

The financial sector impacts of drought are less pronounced in the case of more frequent, less severe droughts, as highlighted for the 1-in-50-year drought scenario in Table 14. Such events can nonetheless have substantial impacts on individual firms and affect livelihoods and poverty.

TABLE 14
Summary of the impact on the financial sector metrics for 1-in-50-year drought scenario under historical climate conditions

Variable		Year 1	Year 2	Year 3	Year 4	Year 5
NPLs ratio						
absolute	**Agriculture**	7.8%	7.88%	8.36%	8.81%	9.14%
difference with BAU		0%	+0.08%	+0.56%	+1.01%	+1.34%
absolute	**Industry and services**	7.8%	7.82%	7.91%	8.04%	8.16%
difference with BAU		0%	+0.02%	+0.11%	+0.24%	+0.36%
PD percentage point *(difference with BAU)*	**Agriculture**	0	0.06	0.36	0.8	1.16
	Industry and services	0	0	0.02	0.05	0.07
CAR percentage loss *(difference with BAU)*	**Banking sector**	0%	(0.08%)	(0.52%)	(1.21%)	(1.85%)

For pluvial flood, the macroeconomic impacts are more muted for more frequent, less severe flooding, as highlighted in Table 15 for the 1-in-50-year pluvial flood level scenario. For example, the maximum GDP loss over the modeled shock period is 0.25% in the case of the 1-in-50-year pluvial flood level scenario, compared with 1.57% in the case of the 1-in-500-year pluvial flood level scenario. This relative difference between the impacts of the 1-in-50-year and 1-in-500-year scenarios is more pronounced in the case of the flood scenarios than the drought scenarios (for which the maximum annual GDP loss of the 1-in-500-year scenario was approximately double that of the 1-in-50-year event). Nonetheless, this less severe but more frequent flooding may still be important, for example, if multiple events occur close in time, resulting in compounding effects.

TABLE 15
Summary of the annual macroeconomic impact of the 1-in-50-year pluvial flood level scenario under historical climate conditions

Variable	Year 1	Year 2	Year 3	Year 4	Year 5
GDP (loss in %)	(0%)	(0.21%)	(0.25%)	(0.20%)	(0.19%)
Consumption (loss in %)	(0%)	(0.23%)	(0.47%)	(0.26%)	(0.13%)
Unemployment rate (absolute)	9.7%	9.91%	9.71%	9.22%	9.29%
(difference with BAU)	0%	+0.27%	+0.17%	-0.2%	-0.03%
Public deficit (% of GDP)	3.57%	3.63%	3.57%	3.34%	3.40%
(difference with BAU)	0%	+0.08%	+0.08%	-0.09%	0.0%

The financial sector impacts of floods are less pronounced in the case of more frequent, less severe floods, as highlighted in Table 16 for the 1-in-50-year pluvial flood level scenario. For example, in the 1-in-50-year pluvial flood level scenario, the NPL ratio peak is less high and occurs earlier than in the 1-in-500-year scenario. The effects on the PD and CAR are also less pronounced in the case of the 1-in-50-year flood level scenario.

TABLE 16
Summary of the annual impact on the financial sector metrics for 1-in-50-year pluvial flood level scenario under historical climate conditions

Variable		Year 1	Year 2	Year 3	Year 4	Year 5
NPLs ratio						
absolute	**Agriculture**	7.8%	7.83%	7.99%	7.9%	7.81%
difference with BAU		0%	+0.03%	+0.19%	+0.1%	+0.01%
absolute	**Industry and services**	7.8%	7.83%	7.95%	7.87%	7.8%
difference with BAU		0%	+0.03%	+0.15%	+0.07%	0%
PD percentage point *(difference with BAU)*	**Agriculture**	0	0	0.05	0.06	0.05
	Industry and services	0	0	0.04	0.05	0.05
CAR percentage loss *(difference with BAU)*	**Banking sector**	0%	0%	(0.04%)	(0.11%)	(0.19%)

Annex IV: **Microlevel banking sector vulnerability assessment**

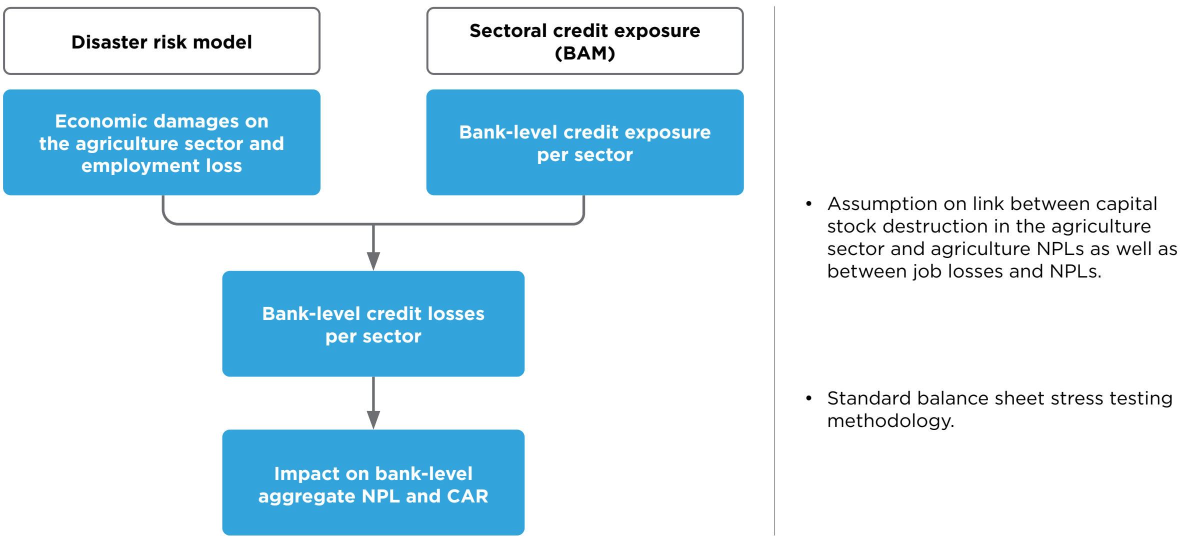
Drought modeling approach

To gauge the potential direct impact of droughts on the banking sector, the assessment links the damages to the agriculture sector (in terms of destruction of capital stock as well as increase in unemployment) with the sector composition of banks' credit portfolio. The assessment therefore uses the five drought scenarios introduced in Section 3.1.2:

a) Three-year historical drought event
b) RCP 4.5 drought scenario occurring in 2030
c) RCP 4.5 drought scenario occurring in 2050
d) RCP 8.5 drought scenario occurring in 2030
e) RCP 8.5 drought scenario occurring in 2050

The impacts of droughts are most directly felt in the agriculture sector. The approach therefore assumes that (i) the destruction in capital stock in the agricultural sector results in a proportional share of agriculture loans turning nonperforming and (ii) job losses result in a proportional share of household sector (consumer and mortgage) loans turning nonperforming.[121] The impact on the asset quality of a bank's agriculture, consumer, and mortgage loan portfolio is then aggregated at the bank level, and standard balance sheet stress test methodologies are used to link the NPL shock with the impact on capital adequacy ratio. The benefit of this approach is that it exploits the bank-level heterogeneity and that the impact on banks is directly linked to their exposure to the agriculture sector as well as the household sector. However, the approach imposes strong assumptions on the sensitivity of agriculture sector NPLs to a destruction of the capital stock in the agricultural sector as well as between job losses and NPLs. The approach also does not consider general equilibrium effects and macroeconomic feedback loops, such as the impact of droughts on food prices and inflation as well as on imports and the trade balance.

FIGURE 35
Schematic presentation of the drought modeling approach



121 For modeling the banking sector impact, the three-year cumulative capital stock destruction and loss in employment are used as outlined in Sections 3.1.2 and 3.1.4.

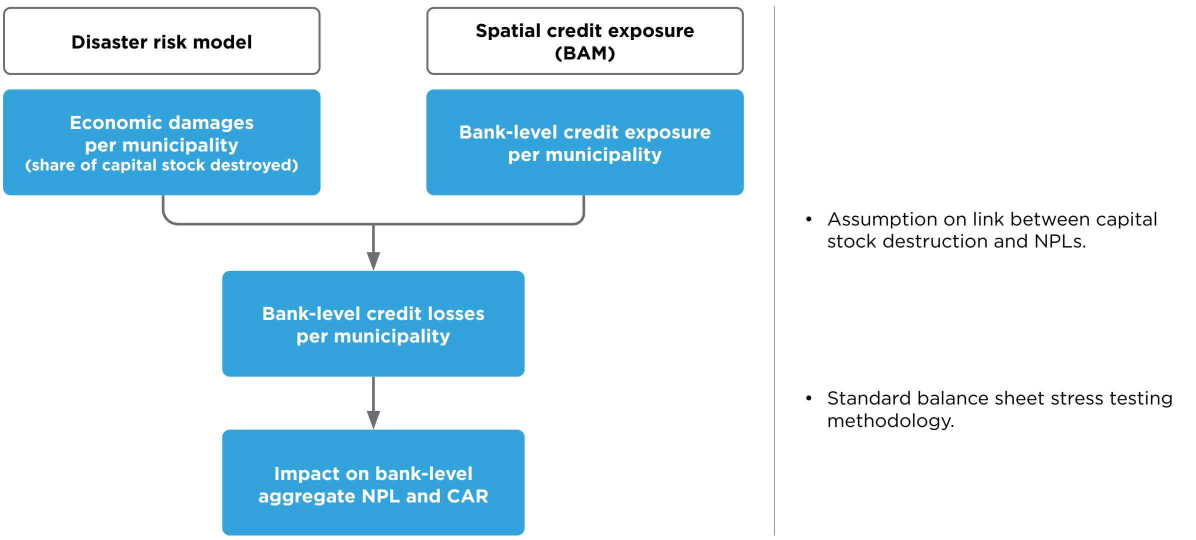
Flood Modeling Approach

The vulnerability assessment links the output of the disaster risk hazard models with the information on spatial credit exposure of the individual banks to gauge the potential impact of floods on the banking sector. The assessment uses initially the two historical flood scenarios described in Section 3.1.2 and then discusses the potential impact of climate change:

a) River flooding with an RP of 500 years
b) Pluvial flooding with an RP of 500 years

Since, in contrast to droughts, flood impacts are more concentrated geographically, the approach assumes that the destruction in capital stock in a certain municipality results in a proportional share of bank loans in that municipality turning nonperforming.[122] The municipal-level NPL impact is then aggregated for each bank, and standard balance sheet stress test methodologies are used to link the NPL shock with the impact on capital adequacy ratio. Similar to the assessment for droughts, the benefit of this approach is that the total increase in banks' NPLs is directly linked to the geographic location of its credit exposure and the location of the economic damage. Drawbacks are that it is based on strong assumptions of the link between capital stock destruction and NPLs[123] and that macroeconomic feedback loops are not considered. The results should thus be interpreted with caution and complemented with macroeconomic models that capture aggregate macro effects (i.e., on unemployment, inflation, interest rates, trade, and exchange rates).

FIGURE 36
Schematic presentation of the flood modeling approach



122 The following analysis assumes a one-to-one impact (i.e., in an *x* percent destruction of capital stock in municipality, *y* means that for each bank *x* percent of their loan portfolio in that municipality turn nonperforming).
123 This link could be specified through regression analyses, but the required timeseries information on the capital stock and NPLs per municipality are not available.

Annex IV: **Sectoral matching**

EITE	Orbis US SIC 2-digits	BAM Credit classification
Agriculture, forestry, and fishing	1, 2, 7, 8, 9	AGRICULTURE, PÊCHE
Mining and quarrying	10, 12, 13, 14	INDUSTRIES EXTRACTIVES
Accommodation and food	70	HÔTELLERIE INDUSTRIES
Manufacturing	20–39	MANUFACTURIÈRES
Nonelectricity utilities	46, 48	
Electricity	49	ENERGIE ET EAU
Construction	15–17	BÂTIMENT ET TRAVAUX PUBLICS
Wholesale and retail trade	50–59	COMMERCE
Transport	40–45, 47	TRANSPORT ET COMMUNICATION
Other Services	60–67, 72–88	AUTRES SERVICES
Public Services	91–97	

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