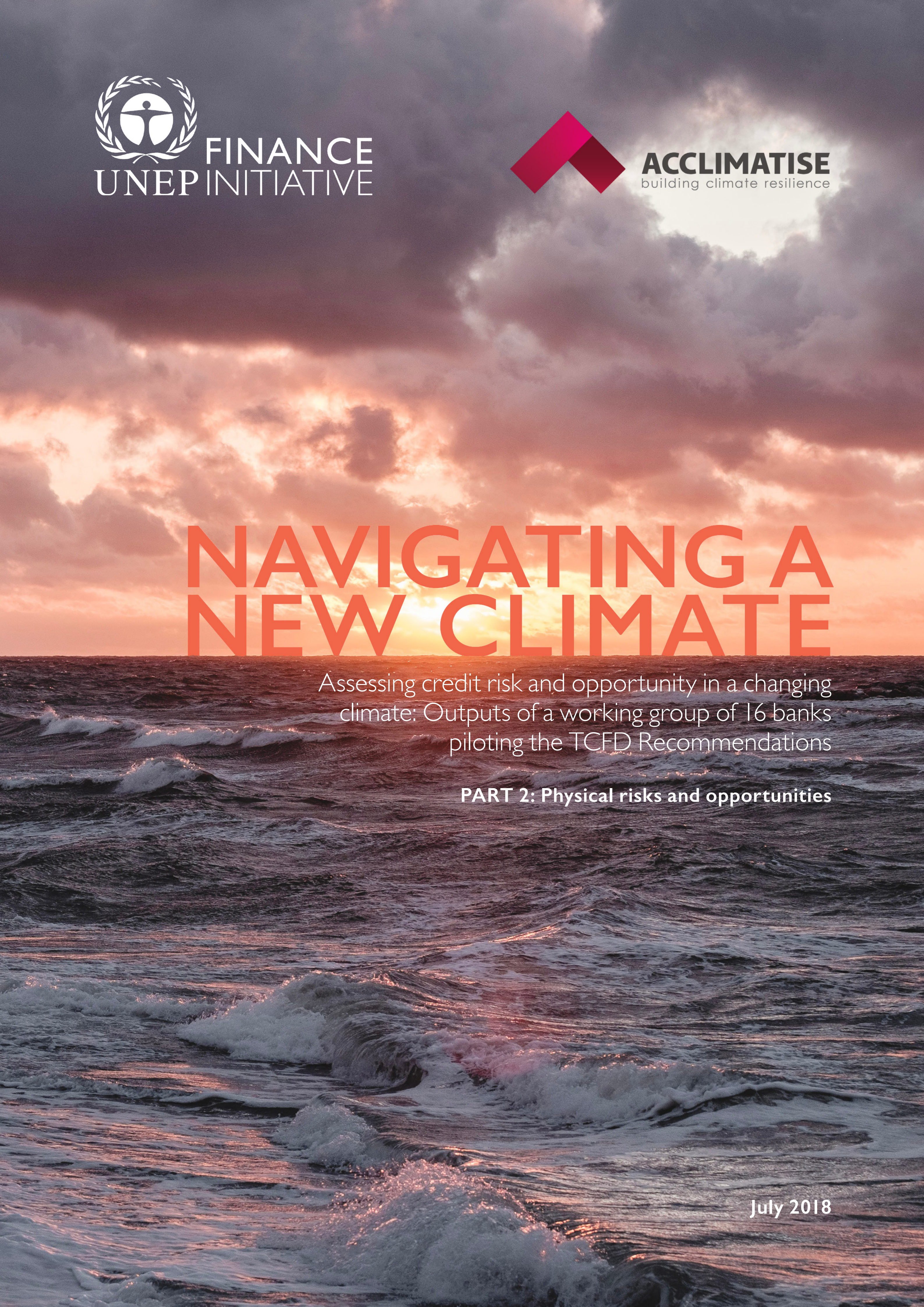

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ACCLIMATISE
building climate resilience

NAVIGATING A NEW CLIMATE

Assessing credit risk and opportunity in a changing climate: Outputs of a working group of 16 banks piloting the TCFD Recommendations

PART 2: Physical risks and opportunities

July 2018

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PERSPECTIVES FROM THE WORKING GROUP

"For financial institutions and other market actors, effectively managing and responding to climate change always means two things: understanding and responding to the intensifying physical impacts of unavoidable climate change; and also mitigating the risks and seizing the opportunities from the decarbonisation of the economy. We are proud of our collaboration with these 16 leading banks and Acclimatise in the development of methods and tools that will help the global financial industry respond to climate change in a holistic manner, spanning both the physical and transition dimensions of the challenge."

ERIC USHER
Head
UNEP Finance Initiative

"RBC believes climate change is one of the most pressing issues of our time and we have an important role to play in supporting the transition to a low carbon economy. We are committed to advancing best practices in climate-related disclosures, assessing climate-related risks and opportunities, and supporting our clients in doing the same."

DAVE MCKAY
President & CEO
Royal Bank of Canada

"While we are still in the early stages of testing this approach, we expect it will be a useful framework to inform our ongoing discussions with customers regarding their climate-related risks and opportunities. Our participation in this working group along with our peer banks aligns with our purpose of shaping a world where people and communities thrive."

KEVIN CORBALLY
Chief Risk Officer
ANZ

"As global temperatures rise, we are seeing rising sea levels, changing weather patterns, extreme weather and more severe and frequent natural disasters. The UNEP FI physical risk methodology provides us with a useful tool in helping the financial industry and our clients understand and prepare for the realities of climate change."

BRANDEE MCHALE
Director of Corporate Citizenship
Citi
President
Citi Foundation

"Climate change will bring wide-ranging risks and opportunities for the banks, so we must prepare proactively in a robust manner; today's UNEP FI TCFD report is a critical first step for us in developing the tools to analyse, respond and report on the physical risk aspect."

ROSELYNE RENEL
Global Head, Enterprise Risk Management
Standard Chartered

"The physical impacts of climate change may pose a risk to banks' loan portfolios. The innovative methodologies in this report provide foundations which can be built upon, as research and data analytics improve. Once banks understand the scale of the risks, this will be a milestone that will encourage other corporates to take climate risk management seriously. Building resilience to physical climate impacts also presents banks with investment opportunities. Those that understand this best will have a competitive advantage."

DR RICHENDA CONNELL
CTO and co-founder
Acclimatise

"The results of the Financial Industry TCFD pilot are a major advancement in the management of the financial risks related to the impacts of climate change. They have the potential to influence the practices of clients, investors and, consequently, the entire economy."

DENISE PAVARINA
Executive Director
Banco Bradesco
Vice-chair
Task Force on Climate-related Financial Disclosures (TCFD)

"This report provides a practical way to assess the physical risks of climate change, which we have piloted on our real estate mortgage portfolio to consider how flood risks could impact Barclays' customers now and in the future. This type of assessment helps us to manage climate change risk and opportunity, both at a transactional and portfolio level."

JON WHITEHOUSE
Head of Government Relations & Citizenship
Barclays

"As Australia's largest agri-business bank, banking one in three farmers in Australia, we understand the seasonal nature of the industry, and the challenges our customers face operating in one of the driest continents in the world. Climate projections indicate these challenges will grow, so it's vital we continue to understand the impacts and opportunities presented by the physical impacts of climate change, to proactively manage future risks and develop opportunities for adaptation and building resilience. This project is helping us to deepen our understanding of physical climate impacts across a range of sectors, so we can continue to support our customers as they manage and mitigate climate-related risks, and identify opportunities for growth. We are pleased to be part of this collaborative global project which is developing new approaches to incorporating climate risk into traditional bank scenario development and stress testing."

DAVID GALL
Chief Risk Officer
National Australia Bank

"For BBVA it has been very helpful to participate in this collective pilot exercise developing an open methodology to assess the impact of physical climate risk in real estate portfolios. It is another great step to progressively internalize climate change in our decision-making."

ANTONI BALLABRIGA
Global Head of Responsible Business
BBVA

"At TD Bank Group we believe that as the transition to a low-carbon economy unfolds, having a firm understanding of climate-related risks and opportunities will be important to help sustain healthy and balanced growth. An interesting area of development is the role of technology in assessing the impacts of a changing climate. In piloting the Financial Stability Board's climate-related recommendations we collaborated with Bloomberg MAPs to assess the ability of data visualization tools to contribute to the assessment process and will continue to explore it applications."

NICOLE VADORI
Head of Environment
TD

"Rabobank's participation in the UNEP FI pilot on the implementation of the recommendation of the TCFD is in line with our mission of Growing a Better World Together. The partnership with leading international organizations like UN Environment helps us in our drive to make a serious contribution to tackling the challenges brought about by climate change. The knowledge developed within the UNEP FI TCFD working group is an important stepping stone that can help us realize our commitment to the Paris Agreement targets."

BAS RÜTER
Director of Sustainability
Rabobank

"As a financial institution we are mindful to the changes that directly impact the society, the economy and the business environment.

The physical risks associated with climate change must be incorporated into banking products and services in order to better understand our exposure to them, anticipate their impacts and provide responses that mitigate their effects and support the transition to a low carbon economy. The financial sector is the driver of this transformation. We are proud to have been part of this working group that has joined the efforts of 16 banks under the coordination of UNEP FI to build a tool for analyzing the impact of physical risks on the banking business. We are committed to advancing our understanding and actions related to Climate Change."

DENISE HILLS
Head of Sustainability
Itaú Unibanco

"The UNEP FI TCFD pilot working group has supported the banking sector in advancing physical climate risk analysis offering an excellent platform for collaboration and knowhow exchange. We are proud to be part of that working group and continue to support joint efforts that help advancing climate risk analysis across financial and non-financial industries."

LISELOTTE ARNI
Managing Director, Head Environmental and Social Risk
UBS

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DISCLAIMER

Acclimatise Group Ltd ("Acclimatise") was commissioned by the UN Environment Finance Initiative ("UNEP FI") Working Group, which includes the following sixteen banks: ANZ, Barclays, BBVA, BNP Paribas, Bradesco, Citi, DNB, Itaú, National Australia Bank, Rabobank, Royal Bank of Canada, Santander, Société Générale, Standard Chartered, TD Bank Group, and UBS (the "Working Group"), to assess climate-related physical risks and opportunities for banks' corporate credit portfolios.

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PROJECT INTRODUCTION

This report is the result of a collaboration of sixteen of the world's leading banks coordinated by the UN Environment Finance Initiative (UNEP FI) Secretariat to advance recommendations published by the Financial Stability Board's Task Force on Climate-related Financial Disclosures (TCFD). Through this collaboration, banks set out to develop and test a widely applicable scenario-based approach for estimating the impact of climate change on their corporate lending portfolios as recommended by the TCFD. As a pilot exercise, the output of this process is intended to provide a first, but critical step, in a longer process of responding to the TCFD recommendations.

The TCFD recommendations urge banks to use scenario analysis to disclose the "actual and potential impacts" of climate-related risk and opportunities on their business as well as how they identify, assess and manage climate risks. In this framework, climate risk falls into two categories: physical risk and transition risk. To assess both sides of climate risk, the sixteen banks formed a Working Group supported by two advisory firms: Acclimatise Group Ltd on physical risk and opportunities, and Oliver Wyman and its sister company Mercer on transition risk and opportunities. The Working Group tested the potential impacts of climate risk under three scenarios, representing a 1.5°C, 2°C, and 4°C global average temperature increase by the end of the century. For physical risk, the group focused on the 2°C and 4°C scenarios to reflect a range of changes in climate and their associated impacts, for which published assessments are widely available.

This report focuses on physical risk, which is the risk resulting from climate variability, extreme events and longer-term shifts in climate patterns, and constitutes the second in a two-part series publishing both the physical risk and transition risk assessment methodologies developed through the Working Group's collaboration. The first report in the series 'Extending our horizons: Assessing credit risk and opportunity in a changing climate: Outputs of a working group of 16 banks piloting the TCFD Recommendations' was published in April 2018.

Acclimatise, a specialist advisory and analytics company focused exclusively on climate risk assessment and adaptation planning, supported the development of the methodology outlined in this report. Developing a widely applicable and rigorous methodology for assessing physical risk relied heavily on the active participation of Working Group members' sustainability, credit risk, stress testing, and finance teams.

EXECUTIVE SUMMARY

KEY MESSAGES

The physical risks from a changing climate may differentially affect the financial health of businesses and impact the financial performance of sectors, creating risks and opportunities for those financing or investing in them. To date, risks and opportunities resulting from the physical impacts of climate change (due to more frequent and extreme weather and climate events, and gradual shifts in climate patterns) have received attention within the insurance sector, but have not been widely assessed in credit and lending portfolios held by banks. Greater emphasis appears to have been placed on transition-related risks and opportunities resulting from the shift to a low-carbon economy. The Financial Stability Board's Task Force on Climate-related Financial Disclosure's (TCFD) Recommendations provide a common framework for disclosures, while leaving banks and other organizations to develop methodologies and approaches for implementing the disclosure recommendations.

The sixteen banks in this pilot project, with the support of climate change experts from Acclimatise, have developed methodologies to assess the risks and opportunities from the physical impacts of climate change on their loan portfolios. These efforts were coordinated and convened by the UN Environment Finance Initiative (UNEP FI).

Banks can begin to assess physical climate risks in their loan portfolios for climate-sensitive sectors using climate change scenarios and methodologies which evaluate impacts on key credit risk metrics. The methodologies presented in this report describe some of the impacts of climate change scenarios on borrowers' revenues, costs and property values, and estimate how these changes could affect the Probability of Default (PD)[a] and Loan-to-Value (LTV) ratios[b] at a borrower and portfolio level. However, there are limitations and challenges in the methodologies which remain to be addressed in future iterations.

Assessments of the physical risk of climate change need to consider the impact of both incremental shifts in climate conditions and changes in extreme events. Incremental changes in climate (such as rising temperatures and changes in precipitation patterns) can affect economic output and productivity, while extreme events can lead to damage, operational downtime and lost production for fixed assets, and potential changes to property value. Extreme events, which are increasing in both frequency and intensity, often attract more attention as their impacts are more apparent. However, the risks from incremental changes, which are already underway, should not be overlooked. Extreme events may only occur in specific locations (such as floodplains or tropical cyclone regions) and require banks to have the ability to assess the probability of their borrowers being impacted by these events. In contrast, incremental changes have the potential to gradually erode the financial performance of entire borrower segments.

Banks can also begin to evaluate the growing opportunities to support borrowers' finance requirements in adaptation. The Working Group has developed a framework for banks to assess strategic opportunities created by the need for borrowers to implement climate adaptation measures. Furthermore, global markets are developing for providers of climate-related products and services, as companies such as engineering and technology providers are identifying opportunities to capitalize on shifting market trends driven by a changing climate.

This pilot project represents a first step in the development of methodologies, but further work is needed to improve the ability to assess physical risks and opportunities of climate change. The pilot project has identified the need to: access location-based borrower data, improve climate models and datasets that can be applied to assets and industries, integrate the macro-economic impacts of climate change, determine adaptation finance needs, and better understand the evolution of insurance products, premiums and markets. Research, analysis and collaboration on these topics, together with physical risk disclosures by companies across sectors, can help address these needs.

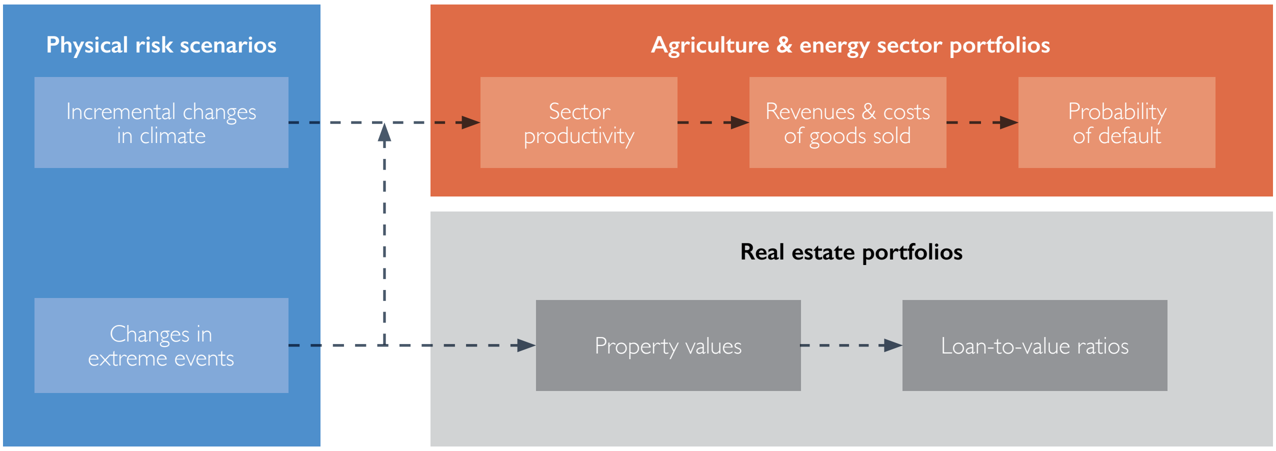
a. Probability of default is assessed for the agriculture and energy sectors only

b. Loan-to-value is assessed for the real estate sector only

ASSESSING PHYSICAL RISK IN LOAN PORTFOLIOS

The methodologies developed in the pilot project reflect the differences in vulnerability to physical impacts of climate change across sectors. The methodologies are piloted across selected climate-sensitive sectors: agriculture, energy and real estate. The methodology for agriculture and energy focuses on analyzing the impacts of incremental climate change and extreme events on borrower revenues and cost of goods sold, and estimating changes in probability of default. For real estate, the methodology assesses potential changes in property values and loan-to-value ratios due to extreme weather events.

Figure 0.1: Overview of the physical risk methodologies



Three combinations of timeframes and temperature scenarios[c] are considered: 2020s – 2°C and 4°C; 2040s – 2°C; and 2040s – 4°C. Peer-reviewed assessments based on these scenarios provide data on incremental climate change impacts on sub-sector performance, such as agricultural yields, crop prices and power production. These are used to estimate changes in revenue for borrowers in these sectors.

A range of extreme weather and climate events are assessed. Impacts on property value, production and revenue losses, and increases in costs are assessed using global and regional datasets on observed frequencies of tropical cyclones, flood, wildfire, drought and extreme heat. Published research provides high-level estimates of future changes in their frequency in the 2020s and the 2040s for the 2°C and 4°C scenarios.

Estimates of changes in revenue, costs and property value are used to evaluate changes in credit risk for individual borrowers and sector portfolios. For borrowers in the agriculture and energy sectors, the financial ratios in rating models which have revenue and cost components are stressed, and revised risk ratings are calculated. For real estate borrowers, estimates of changes in property value due to extreme weather events are used to calculate changes in loan-to-value ratios. A sample of borrowers that are representative of probability of default, loan-to-value ratios and debt ranges in a sector portfolio can be assessed individually, and the findings extrapolated to the whole portfolio. The borrower sample should be representative of the portfolio's geographic distribution, to account for spatial variability in climate conditions. It may also be feasible to analyze whole sector portfolios using existing online risk assessment platforms, although it is important to understand the limitations and model assumptions within these platforms. To improve the quality of the analysis, a deeper understanding is needed of the historic relationships between extreme weather or climate events, and the probability of default and loan-to-value ratios.

The methodologies developed in the pilot project can be applied to a wide range of sectors. The methodology piloted for agriculture and energy sectors could be used to assess changes in credit risk across other sectors, provided that research exists to link changes in climate parameters with production characteristics of the sectors.

c. Scenarios of change in global average temperature by 2100 relative to the pre-industrial era

EVALUATING OPPORTUNITIES

A framework has been developed for banks to begin to assess climate-related opportunities arising from the physical risks of a changing climate. Opportunities are defined in the framework as the potential increase in demand for financial products and services driven by physical risks. The framework provides guidance on undertaking a strategic market assessment and evaluating a bank's institutional capacity and market positioning, in order to prioritize the most promising opportunities. Banks can identify sectors with high market potential in which the bank is well-positioned to take advantage of opportunities.

A taxonomy of climate-related opportunities has been created. The taxonomy recognizes that some of the effects of a changing climate are already occurring, and financial products and services can help borrowers undertake actions to manage existing risks, such as extreme event preparation and post-event recovery. Banks can also provide products and services to assist borrowers in responding to the risks which are beginning to emerge, and in preparing for significant changes in markets in the further future. For example, in the retail mortgage sector there may be increased demand for loans for home improvements to cool houses in areas where cooling has not previously been needed; in agriculture, farmers may change their business models in response to climate change and move into alternative crops.

THE WAY FORWARD

Building climate resilience is a journey; the pilot project has broken new ground, but more work lies ahead. The results of the pilot project highlight several factors potentially affecting the financial performance of borrowers which cannot be properly assessed at present, including macro-economic impacts, adaptation finance needs, and future actions of governments and insurers. As a result, the assessments of climate impacts on borrowers may be incomplete. Filling these gaps will improve the robustness of future assessments. Communication and collaboration between banks and stakeholder groups is needed to take this forward effectively.

Improved collaboration with the climate and economic research community can help to strengthen the evidence base underpinning physical risk assessments. Key areas for development are improved spatial data on future changes in extreme weather and climate events, and further research on the macro-economic impacts of physical climate risks. At present, macro-economic modeling approaches provide a wide range of estimated impacts on gross domestic product (GDP). Furthermore, there is very little research on how physical climate change will affect broader macro-economic indicators such as inflation and interest rates. This is a key research gap.

Improved tools and spatial modeling expertise on the physical impacts of climate change are needed for banks to better quantify physical risks and opportunities. Analytical tools are beginning to emerge which facilitate banks' assessments, such as spatial risk analysis platforms, although there are challenges with how these platforms interact with borrower data. Platforms should be developed and improved to incorporate analytics for evaluating physical risks in borrower's value chains. There is also a requirement for more market assessments on sector adaptation finance needs.

Improved collaboration between banks, borrowers, governments and the insurance industry would increase the quality of forward-looking disclosures. Improved disclosures by businesses across all sectors will aid banks in evaluating the risks in their loan portfolios, and will also help banks to identify opportunities to support their borrowers. Governments provide essential risk mitigation measures against extreme events and incremental climate change impacts, including flood defenses, climate-related standards for critical infrastructure such as water resources and energy, and financial backing of insurance schemes. Government policy and regulation on adaptation in these areas can have a profound impact on banks' borrowers. The insurance industry has been vocal about climate change for decades; however, it is unclear how insurance availability and pricing will change in the future, as a result of the impact of climate change. Transparency and collaboration in these areas will enhance decision-making for all.

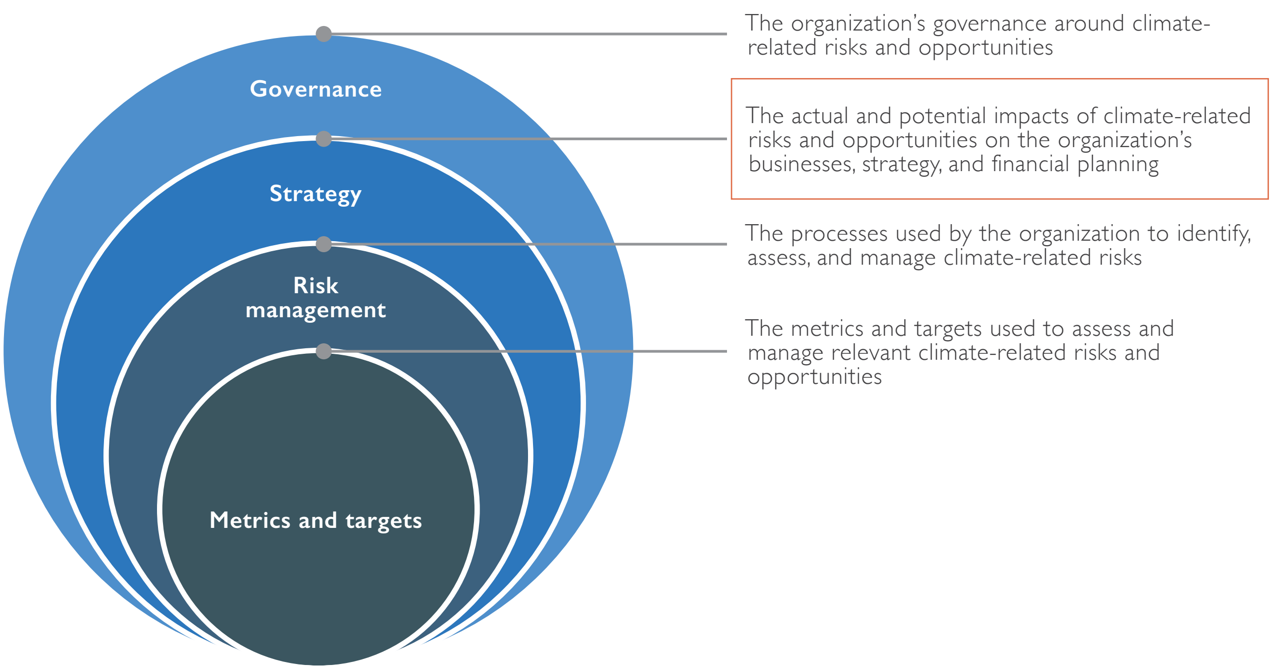
1. INTRODUCTION: PREPARING BANKS FOR THE IMPACTS OF A CHANGING CLIMATE

The Financial Stability Board's Task Force on Climate-related Financial Disclosures (TCFD) published its recommendations in 2017 for the voluntary disclosure of climate-related risk and opportunities by financial institutions and other entities. These have provided the impetus for many organizations to progress climate risk and opportunity assessment. Over 280 organizations have already signed statements supporting the recommendations. High-level initiatives have been created to advance guidance that builds on the common framework provided by TCFD,[d] and various industry groups are piloting approaches to implementing the recommendations.

TCFD identifies physical risk as one of two categories of climate-related risk, alongside transition risk to a lower-carbon economy. It recognizes that physical risks may have financial implications for organizations, including banks, and that the timing and severity of the impacts can be difficult to estimate.

The TCFD provides a clear way forward for banks on disclosure, though its recommendations are not prescriptive. The TCFD recommendations[1] provide guidance across four core elements: governance, strategy, risk management, and metrics and targets (Figure 1.1).

Figure 1.1: Core elements of recommended climate-related financial disclosures



d. For instance the European Bank for Reconstruction and Development (EBRD) and the Global Centre for Excellence on Climate Adaptation (GCECA) published guidance 'Advancing TCFD Guidance on Physical Climate Risk and Opportunities' in May 2018. The guidance is available at: www.physicalclimaterisk.com

This report aims to help banks begin to address the "Strategy" element of the TCFD recommendations, which requires forward-looking scenario-based assessments of risks and opportunities. TCFD outlines three recommended disclosures within the "Strategy" element that organizations (including banks) should address:

a. The climate-related risks and opportunities the organization has identified over the short, medium, and long term;

b. The climate-related risks and opportunities on the organization's businesses, strategy, and financial planning; and

c. The resilience of the organization's strategy, taking into consideration different climate-related scenarios, including a 2°C or lower scenario.

This report sets out initial methodologies for banks to assess the risks and opportunities from the physical impacts of climate change in their loan portfolios, to help banks make progress on these topics. The report also provides case studies from banks who have piloted the methodologies, to provide practical experience and insights into the challenges and benefits of undertaking these assessments.

2. AN INTEGRATED APPROACH FOR PHYSICAL RISK ASSESSMENT

A changing climate can affect banks' borrowers and the financial performance of sectors in a variety of ways, directly and indirectly. The potential impacts include damage to fixed assets, changes in output, disruptions to supply chains, and shifting patterns in demand for goods and services. Climate change may weaken a company's balance sheet through loss of revenue as productivity declines, impacts on asset values, or increased costs as raw materials become scarce, or operations need to change. The significance of the impacts will vary across geographies and time horizons, between different industry sectors and individual borrowers. More indirectly, the macro-economic impacts of climate change, together with changes in government policy and regulation on adaptation, and the response of the insurance industry to increasing risks all have potential to affect the financial health of borrowers and the credit risk in banks' loan portfolios.

Faced with this complexity, the task of assessing physical climate risk can appear daunting; however banks can take steps to evaluate the risks in loan portfolios. For some risk factors, initial quantitative assessments can be undertaken, drawing on published research and empirical evidence. The physical risk methodologies presented in this Chapter describe how banks can deliver these high-level quantitative assessments, by evaluating plausible linkages between climate change, risks to sector performance, financial risk to borrowers and associated credit risks. Some other factors are more uncertain, including the macro-economic impacts of climate change, future government policy and regulation, future changes in the insurance market, and the scale of investment in adaptation and resilience. These factors are not quantified in the pilot methodologies. Nevertheless, they can be evaluated qualitatively, and there is value for banks in doing this. In these areas, developments are needed to improve future assessments, and these are set out in Chapter 5.

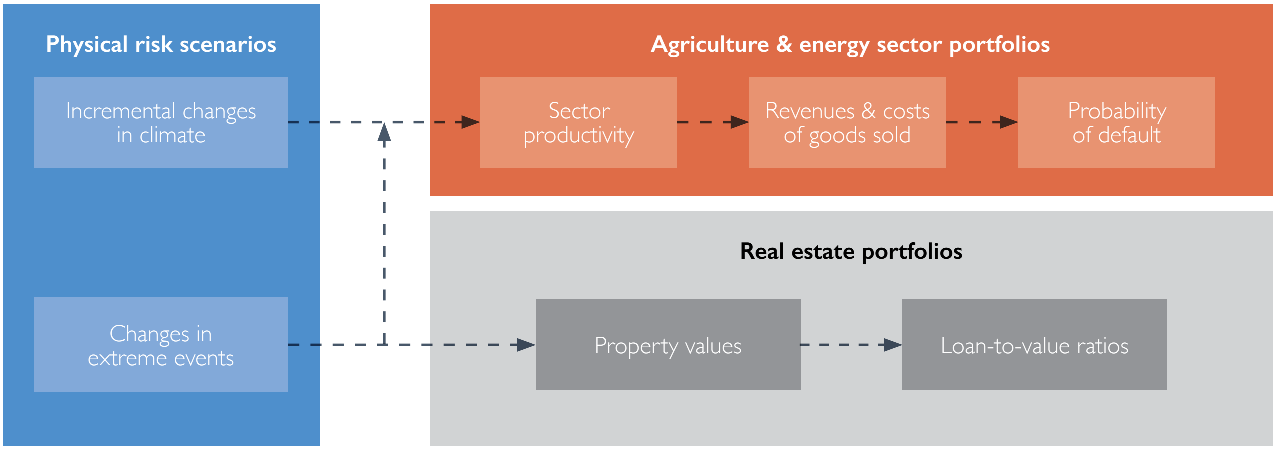
The pilot project aimed to develop climate change scenarios and methodologies which can be used in-house by banking teams, drawing on publicly-accessible models and data. These aims helped to frame the approach to developing the methodologies, as explained in Table 2.1. Future improvements are also identified, which are further discussed in Chapter 5.

Table 2.1: Boundary conditions for the pilot project and their implications for the physical risk methodologies

The methodologies should be suitable for banks to implement in-house.	The methodologies take account of banks' existing data, capacities and tools. Banks may not hold in-house data on borrowers' fixed assets (locations and characteristics). Most banks currently use spreadsheet-based tools, which are not best suited to spatial risk analysis.	Development of spatial risk analysis platforms which incorporate data on borrowers' fixed assets and climate risks can facilitate banks' assessments. Development of in-house capacities within banks to undertake spatial risk analysis using Geographical Information Systems (GIS) would improve the quality of assessments.
The methodologies and datasets should be universally applicable but should also reflect national and local realities and variations.	The pilot project utilizes climate-related datasets which provide global coverage at the highest available spatial resolution.	Higher quality datasets may be available for specific countries. Banks can identify the best available datasets for their countries of operation.
The models and data underpinning the methodologies should be publicly-accessible.	Some potentially important physical risks are not included due to a lack of publicly-accessible data and tools (e.g. for evaluating physical risks to company value chains).	Improvements can be made to models, data and risk assessment platforms to address gaps.

While acknowledging the gaps in knowledge, data and tools, physical climate risks in banks' loan portfolios can begin to be assessed using climate change scenarios and methodologies that evaluate impacts on key credit risk metrics. The methodologies presented in this Chapter explain how banks can evaluate the impacts of climate change scenarios on borrowers' revenues, costs and property values, and how this could affect the Probability of Default (PD) and Loan-to-Value (LTV) ratios at a borrower and portfolio level. The overall approach is summarized in Figure 2.1.

Figure 2.1: Overview of the physical risk methodologies



The methodologies developed reflect the differences in vulnerability to climate change impacts across sectors. These methodologies, which vary by sector, were piloted on material climate-sensitive sectors: agriculture, energy and real estate. These sectors were subdivided into sub-sectors to provide a deeper examination of the differences in climate vulnerability at the sub-sector level. The sectors and sub-sectors piloted are presented in Table 2.2.

Table 2.2: Sectors and sub-sectors included in the pilot project

Agriculture	Crop production Livestock farming Timber production
Energy	Thermal power production Hydropower production Power transmission Oil and gas upstream (exploration & production) Oil and gas midstream and downstream (liquefied natural gas, gas-to-liquids, refining, petrochemicals)
Real estate	Retail mortgages Commercial (income-producing) real estate

Two physical risk methodologies have been developed for the three pilot sectors. One methodology enables banks to analyze credit risk for borrowers in the agriculture and energy sectors. It focuses on analyzing climate-related impacts on borrower revenues and cost of goods sold (also known as 'cost of sales'), and estimating changes in probability of default. A second methodology, for real estate, enables banks to assess potential changes in property values and loan-to-value ratios due to extreme weather events. This methodology is applicable to retail mortgages and income-producing real estate.

A wider range of sectors could be analyzed using the methodologies. The methodology piloted for agriculture and energy, in particular, could be used to assess changes in credit risk across other sectors, provided that research exists to link changes in climate parameters with production characteristics for the sector.

The methodologies can be used to undertake forward-looking portfolio-level assessments based on current portfolios. The methodologies allow banks to evaluate the sensitivity of current loan portfolios to future climate change scenarios. It is recognized that future loan portfolios will be different from today's, but many assumptions would be required to model portfolio evolution and these would be subjective, preventing comparability between banks. Furthermore, some of borrowers' current operating assets may be retired in the future and new assets may be installed. However, evaluating projected future impacts on the current portfolio can facilitate strategic planning. Therefore, for the purpose of the analysis it is assumed that banks' loan portfolios in the 2020s and 2040s will be the same as today. To evaluate portfolio-level impacts, a sample of borrowers that are representative of probability of default, loan-to-value ratios and debt ranges in a sector portfolio can be assessed individually, and the findings extrapolated to the whole portfolio. The borrower sample should be representative of the portfolio's geographic distribution, to account for spatial variability in climatic conditions. It may also be feasible to analyze whole sector portfolios using existing online risk assessment platforms.

2.1. BORROWER CHARACTERISTICS

The physical risk methodologies require input data on borrower characteristics. Existing financial metrics for borrowers form the starting point and are key data inputs. Following the steps described in Sections 2.3 to 2.5, these metrics are adjusted to take account of physical climate risk. For agriculture and energy, data on annual revenue and cost of goods sold (COGS) are extracted from borrowers' recent income statements. Data on borrowers' key operating assets, their locations and their output are also required. The latter is important because physical climate risk can vary considerably from one location to another. However, for larger commercial clients with more than one operating asset, banks often do not have in-house data on asset locations and output. Hence, there is a trade-off between the effort involved in obtaining these data and undertaking the analysis at a finer spatial scale vs. the quality of the assessment. For real estate, the required data inputs are property locations, property values, outstanding loan amounts and average remaining loan terms for the portfolio. These data are held by banks, but datasets may require collation and processing before they can be analyzed efficiently. Furthermore, bank protocols on privacy and security of client data need to be considered.

2.2. INSURANCE AS A RISK MITIGANT FOR EXTREME CLIMATE AND WEATHER EVENTS

Insurance can help mitigate the effects of extreme events on borrowers, but is excluded from the analysis due to uncertainties about present-day coverage and future changes in insurance availability and pricing. Insurance allows companies and homeowners to transfer risks and reduce losses associated with extreme weather and climate events. Research undertaken for the pilot project found that publicly-available data on present-day insurance uptake across commercial sectors and regions are scarce. This makes it difficult to develop a comprehensive picture of how insurance currently mitigates these extreme events for banks' commercial borrowers. Looking into the future, there are numerous interrelated factors which will influence insurers' decisions to provide coverage (including changing climate risk), making it challenging to evaluate how insurance for banks' commercial and retail borrowers may change. However, there is concrete evidence of insurers having narrowed or withdrawn coverage in the past following extreme weather events,[2] which may give some indication of how insurance markets may react to future changes in these events. Research undertaken on these topics for the pilot project is summarized in Appendix B: Findings of research on insurance. Banks in the pilot project working group sought additional information through research and from insurance industry representatives on these issues, and key findings are summarized in Box 2.1.

BOX 2.1: Understanding insurance as a physical climate risk mitigant

In order to understand whether insurance could be factored in as a physical climate risk mitigant, a number of banks undertook research and met with a range of insurers and re-insurers. In Australia, banks also met with the peak industry body, the Insurance Council of Australia. Key learnings from these discussions highlighted the following:

- Under-insurance[e] is an issue that decreases the effectiveness of insurance as a risk mitigant against the physical impacts of climate change.
- The Insurance Council of Australia provides figures indicating that despite bushfires, floods and cyclones being an annual feature of life in Australia, many households are not covered.[f] Insurers observe that after natural disasters in Australia they see that typically, about one in 20 properties are not insured at all and upwards of 70% of properties are inadequately insured.[3] The Association of British Insurers notes that 64% of UK households are living in their own home (compared to 36% who rent) and reports that "In 2016, approximately 61% of households spent money on home buildings insurance",[4] suggesting a significant majority of UK homeowners have property insurance.
- Insurance coverage for property damage can be available for fire, wind, storm, hail, and flood but the effects of extreme heat are difficult to price and are currently not usually covered. This varies by country.
- Take-up of multi-peril insurance varies across countries. In agriculture, property damage is generally well insured but there is significant variation in the availability and take-up of multi-peril insurance for crops. In 2017, Australia's largest rural insurer IAG, launched a one-year pilot program for a multi-peril crop insurance product for wheat, barley and canola growers to protect farmers against yield shortfall caused by natural perils such as flood, frost, drought and vermin.[5]
- In other sectors like small to medium sized business, property assets may be covered, but businesses may not be covered for business interruption risk.[6] If businesses are located in areas likely to experience greater physical risks from climate change in the future, take-up of this type of insurance may become a more important risk mitigant.
- The short-term nature of insurance products means insurance pricing generally looks at short term (one year) weather forecasts. This is changing in some areas as the insurance industry introduces new products to help customers respond to risks such as climate change, for example, the development of parametric insurance.[7]
- The insurance industry is investigating the impacts of extreme weather, under a range of climate scenarios, on insured losses. For example, see the Association of British Insurers research on windstorm losses.[8]

Based on this information, it was decided to use a worst-case scenario and assume no insurance coverage for the purpose of assessing physical risk in banks' loan portfolios.

Finally, the UNEP FI TCFD pilot project with insurance companies may address some of the questions mentioned above. It may allow banks to improve their assumptions about insurance, and in turn provide more complete analysis of physical climate risk.

e. The Australian Securities and Investment Commission defines underinsurance for a property as when insurance coverage is less than 90% of the rebuilding costs. Refer to: www.moneysmart.gov.au/insurance/home-insurance/risk-of-underinsurance. [Last accessed: 28 June 2018]

f. Dr Richard Tooth and Dr George Barker of the Centre of Law and Economics noted in their 2007 report 'The Non-Insured, Who, Why and Trends' prepared for the Insurance Council of Australia that, of Australia's 7.7m households, 23% (1.8m) of residential households are estimated not to have a building or contents insurance policy.

2.3. CLIMATE CHANGE SCENARIOS

According to the Intergovernmental Panel on Climate Change (IPCC) – the world's leading scientific body in this field – man-made climate change is already underway.[9] Each of the past three decades has been warmer than the decade before and warmer than any decade since records began. Sea levels are rising, and Arctic ice cover is shrinking. It has been getting wetter, and storms and heat waves are becoming more intense. Looking forward, extreme precipitation events will likely become more intense and frequent in many regions, and heat waves are likely to last longer and occur more frequently. The oceans will continue to warm, and global mean sea level will continue to rise.

The physical risk methodologies explore a range of potential climate futures out to the 2040s, representing different global climate change mitigation ambitions. In the near-term and mid-term, changes in climate due to past and present-day greenhouse gas emissions are already locked into the climate system, and the physical risks are already being felt. Hence, there is no significant difference in physical risk in the 2020s under different greenhouse gas emissions scenarios, and only a small divergence by the 2040s. However, over the longer-term the degree of physical risk is largely determined by which emissions trajectory is followed from now onwards, and from mid-century the extent of climate change under higher emissions scenarios is expected to be much more significant than with lower emissions. To explore a range of potential climate futures, the methodologies assess physical risks for three combinations of timeframes and temperature scenarios:[g] 2020s – 2°C and 4°C; 2040s – 2°C; and 2040s – 4°C. The 2°C scenario corresponds to Representative Concentration Pathway (RCP) 2.6 and the 4°C scenario, to RCP 8.5 (the latter being the current trajectory based on present-day emissions). The 2020s and 2040s are centered on the years 2025 and 2045 respectively.

The methodologies consider the physical impacts from incremental (chronic) climate change and extreme (acute) weather and climate events. Incremental climate change represents the slow, 'creeping' manifestations of longer-term climate change over several decades, such as rising temperatures and changes in precipitation patterns. Extreme events represent acute climate variability and may only occur in specific locations, such as floodplains or tropical cyclone regions. Extreme events often attract more attention as their impacts are more apparent. However, the risks from incremental changes, which are already underway, should not be overlooked. They have the potential to gradually erode the financial performance of entire borrower segments on an ongoing basis.

Incremental climate change impacts are assessed using the outputs of sector-specific climate change impact models. As discussed in Section 2.4.1, the physical risk methodology for agriculture and energy draws on published climate change impact studies which describe how incremental climate changes (e.g. for temperature and precipitation) could affect sector productivity in the future (e.g. agricultural yield).

The impacts of extreme events are assessed using online data portals. The methodologies recommend that banks undertake the extreme event analysis at the highest possible spatial resolution, ideally for the specific locations of borrower's fixed assets. The extreme events covered in the methodologies are: cyclone, flood, wildfire, drought and extreme heat. Not all extreme events are relevant for all sectors and geographies. For instance, drought and extreme heat are not considered for real estate. There are several web-based portals providing maps and data on baseline extreme events[h], though these have limitations (see Box 2.2).

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g. Change in global average temperature by 2100 relative to the pre-industrial era

h. In addition to Princeton Climate Analytics' drought risk product, there are publicly-available datasets from UNEP GRID Global Risk Data Platform and ThinkHazard! (developed by the Global Facility for Disaster Reduction and Recovery, GFDRR), and commercial tools such as Swiss Re CatNet®.

The extreme event data are expressed in terms of return periods or frequencies[i] for the present-day and future climate scenarios. The starting point for assessing the future impacts of extreme events is to investigate present-day (baseline) return periods or frequencies based on historical records, and then to draw upon research and models to estimate how these may change in the future. Box 2.3 below showcases a drought risk product developed for this pilot project by Princeton Climate Analytics. An unusual feature of this product is that it provides spatial data for baseline and future time periods, at relatively fine spatial scales. Spatial data on the return periods or frequencies of other types of extreme events under future climate scenarios are not available from public data portals; therefore country-level estimates are derived from published research.

BOX 2.2: Limitations of the extreme event analysis

For some types of extreme event, namely flood and cyclone, existing data portals provide maps showing defined return periods for the present-day (e.g. flood maps for return periods of 25, 50, 100 and 200 years). In reality, there will also be other extreme event return periods (e.g. flood return periods of 26, 27, 28 years etc.), i.e. these datasets are sampling a limited number of return periods from the full extreme event distribution.

A further limitation of the extreme events analysis is that data portals do not typically provide maps showing future extreme events (with the exception of the Princeton Climate Analytics product described in Box 2.3 below). Therefore, high-level estimates for the future were identified from the published literature, covering broad world regions or whole countries.

Suggested improvements to enable banks to deliver more robust assessments of extreme events are described in Chapter 5.

i. Frequency is the inverse of return period, i.e. frequency = 1/return period

BOX 2.3: Princeton Climate Analytics (PCA) Global Drought Risk Product

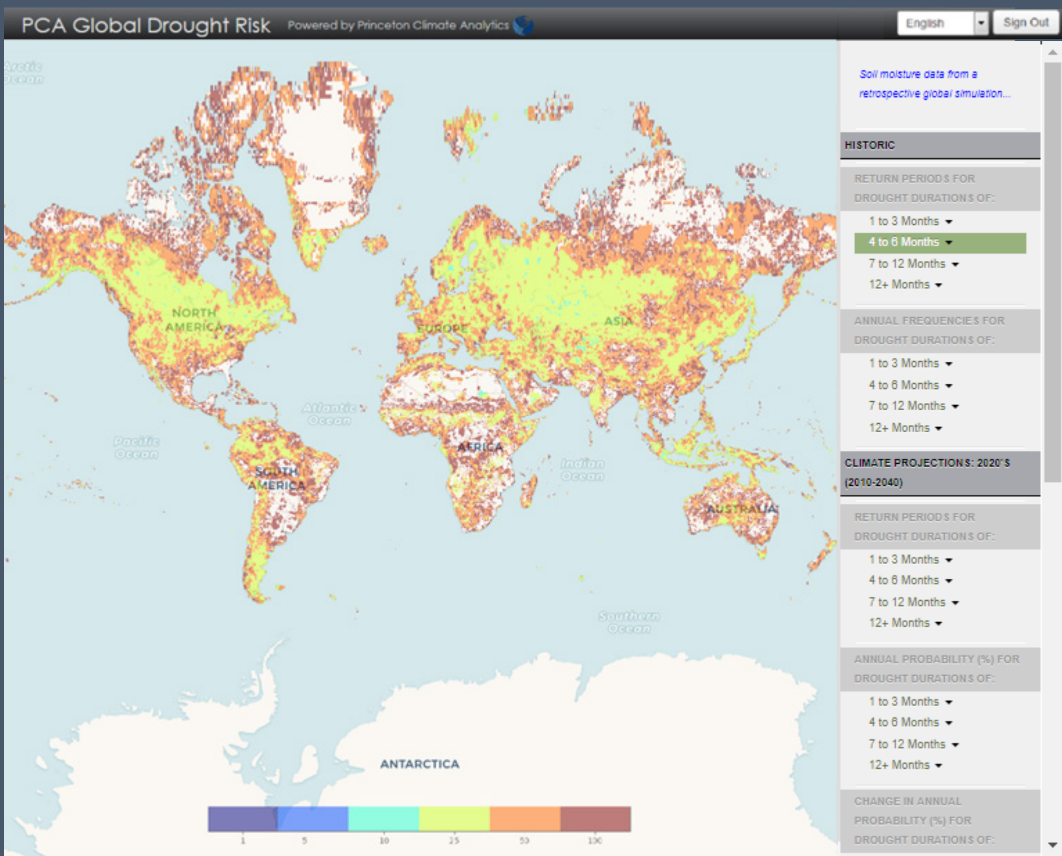
Authored by Princeton Climate Analytics

The PCA drought risk product[10] is based on state-of-the-art global hydrological modeling and climate model data. This map-based product covers both baseline ('historic') and future droughts of various durations (1-3 months, 4-6 months, 7-12 months and 12 months +). The drought maps are presented as either 'return periods' (years) or 'annual frequencies' (%). The PCA product has been used by banks in the pilot project to analyze drought risk to borrowers in the agriculture sector.

The baseline (historic) drought risk product is based on soil moisture data for the period 1950-2016. The dataset was developed using the Variable Infiltration Capacity (VIC) land surface hydrological model, which was run for the period 1950-2016 at high spatial and temporal resolution (0.25-degree latitude-longitude, daily). The model simulation is forced by historic climate data from the latest version of the Princeton Global Forcing (PGF) dataset that combines ground-based observations of climate with satellite remote sensing data globally, and state-of-the-art global datasets of vegetation distribution and soil properties. Drought is defined when soil moisture at a given location falls below the 10th percentile based on monthly average soil moisture.[j] Risk for several drought durations (1-3 months, 4-6, 7-12 and 12+ months) is estimated based on the frequency of drought events in the baseline period.

Future drought risk is based on the latest set of climate model simulations run under the Coupled Model Intercomparison Project Phase 5 (CMIP5) in support of the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC). Future drought risk is estimated as the multi-model average for two future climate scenarios. A total of 15 climate models are considered, which have soil moisture data available for all scenarios. In line with the physical risk methodologies, the future scenarios considered are Representative Concentration Pathways (RCP) 2.6 and 8.5 (i.e. 2°C and 4°C scenarios[k]). Future risk is defined for two future periods for each scenario: the 2020s and 2040s.

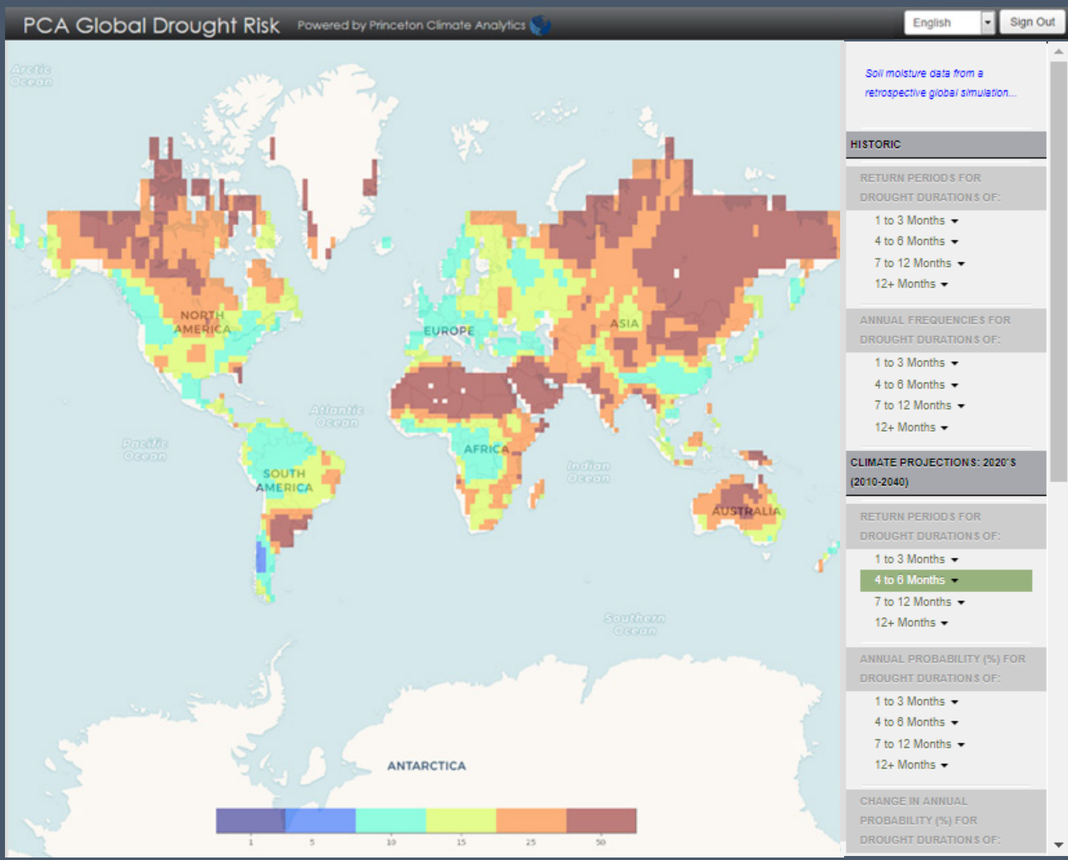
Figure 2.2: Baseline (historic) drought frequency, showing return periods for drought durations of 4-6 months. The color-coded scale depicts return periods from 1 year (dark blue) to 100 year (dark red).



j. There are many ways of defining a drought. Some regions are extremely arid and in these regions the estimates will show less sensitivity.

k. Scenarios of change in global average temperature by 2100 relative to the pre-industrial era

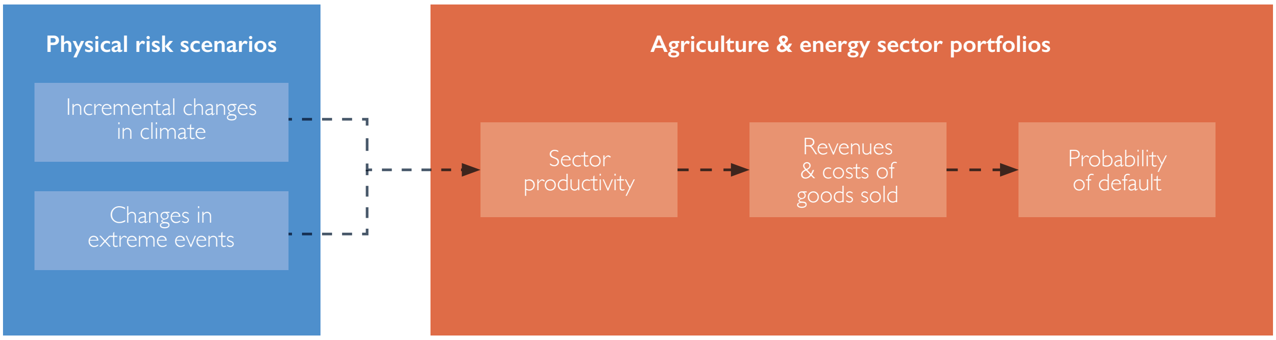
Figure 2.3: Drought frequency for the 2040s 4°C scenario, showing return periods for drought durations of 4-6 months. The color-coded scale depicts return periods from 1 year (dark blue) to 50 year (dark red).



2.4. CLIMATE CHANGE IMPACTS ON PROBABILITY OF DEFAULT

The physical climate risk methodology for agriculture and energy focuses on analyzing the impact of climate change on borrower revenues and cost of goods sold, and estimating changes in probability of default (see Figure 2.4).

Figure 2.4: Overview of the physical climate risk methodology for assessing changes in probability of default for the agriculture and energy sectors



2.4.1. Assessing changes in sector productivity

Incremental climate change can affect the productivity and output of sectors. Changes in temperature, precipitation and related variables can affect productivity and output from many types of economic activity. For instance, the temperature of water used to cool thermal power plants plays a critical role in determining how much power can be generated. For hydropower plants, changes in precipitation, evaporation and snow/glacier melt can all affect river flows, reservoir inflows and ultimately, power production. Modeling studies suggest that incremental climate change will reduce the productivity of many thermal and hydropower plants worldwide.[11]

The impacts of incremental climate change on sector productivity are estimated based on peer-reviewed literature. Drawing upon published climate change impact assessments, the methodology relates incremental climate changes to future changes in sub-sector productivity for the agriculture and energy sectors. Published assessments are used to provide estimated sub-sector productivity changes for world regions and countries. Due to inherent uncertainties in climate models and sector impact models, estimates of change in productivity can often range from positive to negative values. The methodology recommends that banks should assess impacts on their portfolios associated with the conservative, 'worst case' changes (i.e. the largest production losses). An example of a study on incremental climate change impacts on agriculture is provided in Box 2.4.

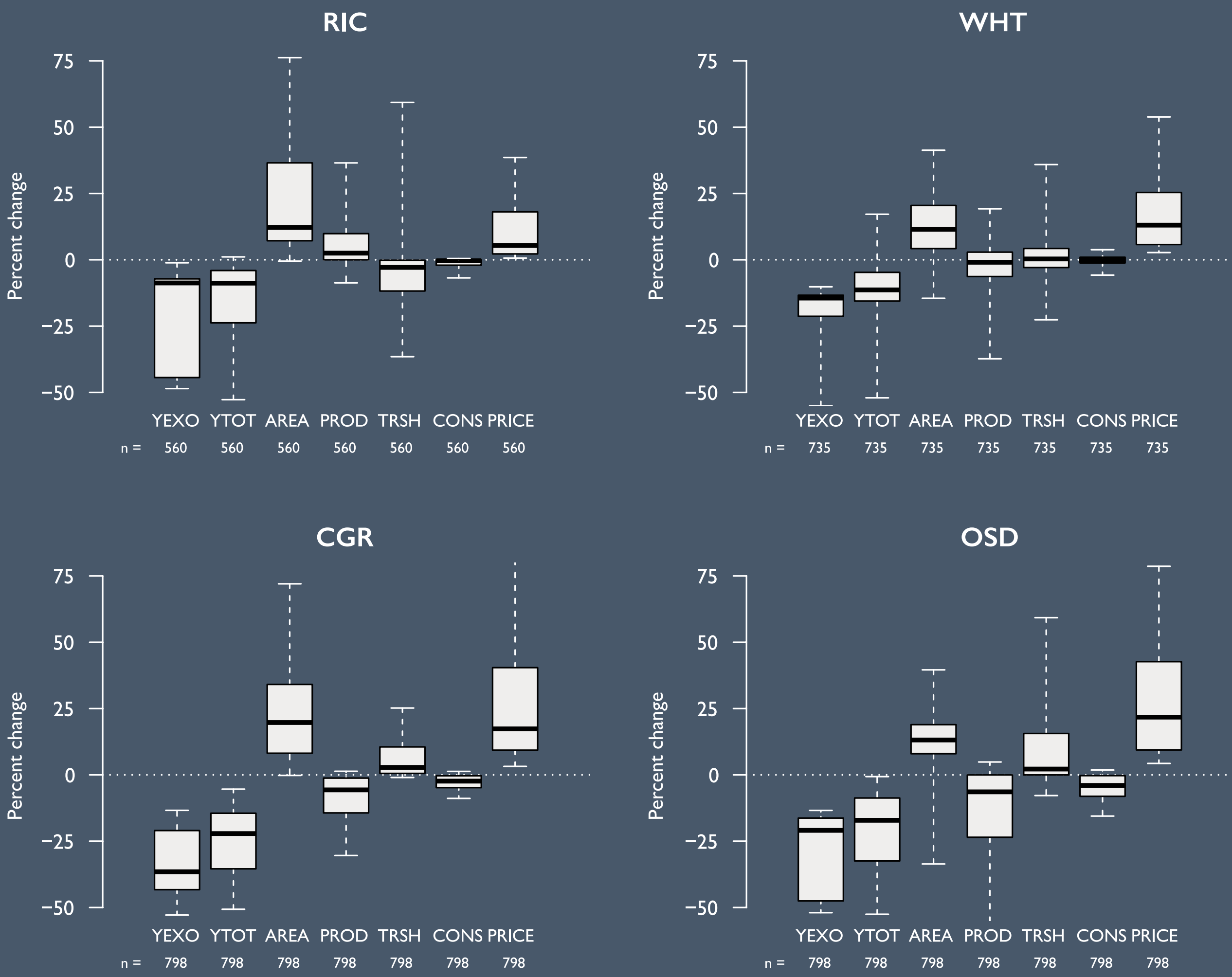
Production losses due to extreme events are estimated from empirical evidence. For agriculture, the methodology provides high-level estimates of the typical proportion of production lost per extreme event type (e.g. proportion of crop lost following a drought). For energy, the impacts of extreme events are expressed as typical 'downtimes' during which production ceases (e.g. downtime for a power plant following a tropical cyclone). Where there is empirical evidence of 'throttling back' of operations rather than complete stoppage (e.g. thermal power plants reducing electricity generation during periods when cooling water is scarce), this is expressed as a downtime equivalent.

Box 2.4: Incremental climate change impacts on agricultural yields and commodity prices

Agricultural productivity, or yield, is sensitive to temperature and precipitation, and thus affected by climate change. Determining climate change impacts in the agriculture sector requires integration of a suite of models that evaluate the interrelationships between climate, crop and economic systems.

Studies on future changes in yield and price due to incremental climate change can be used to assess impacts on industry sub-sectors. For example, research undertaken as part of the Agricultural Model Intercomparison and Improvement Project (AgMIP) by the global agricultural modeling community assessed climate change impacts on four crop aggregates (coarse grains, oil seeds, wheat and rice) which collectively account for approximately 70% of global crop harvested area.[12] The research provides estimates of projected changes in yield (YTOT) and price (PRICE) under a 4°C scenario in 2050 (see USA example in Figure 2.5).[13] The results highlight that across all four crop commodity aggregates, yields are projected to decrease due to climate change, with median reductions of up to 25%. Corresponding commodity prices are projected to increase, reflecting the market price effects of the climate shock.

Figure 2.5: Estimates of changes in yield (YTOT) and price (PRICE) of four crop aggregates (rice, wheat, coarse grains and oil seeds) due to climate change in 2050 under a 4°C scenario: Country-level results for the USA. *Results are available for other world regions and countries.*



RIC = rice, WHT = wheat, CGR = coarse grain, OSD = oilseeds

YEXO = exogenous yield; YTOT = endogenous yield; AREA = harvested area; PROD = production; TRSH = the change in net imports relative to reference scenario production in 2050; CONS = total demand; PRICE = producer price. The variables are reported as percentage change for the 4°C scenario (RCP 8.5) relative to the reference scenario (with constant climate) in 2050. The thick black line represents the median change. Boxes represent first and third quartiles. The whiskers show 5-95% intervals of results.

2.4.2. Adjusting income statement metrics

The next step is to translate climate-related impacts on future sub-sector productivity into adjustments to borrowers' revenues and cost of goods sold (COGS).

Incremental climate change impacts on sub-sector productivity and price are assumed to lead to corresponding changes in borrower revenues. As a simplifying assumption, the percentage changes in productivity and price for industry sub-sectors in specific world regions / countries from climate change impact models are assumed to translate into equivalent percentage changes in annual revenue for all borrowers in that industry sub-sector and world region / country. For agriculture, changes in revenue due to incremental climate change impacts take account of changes in productivity (yield) and price. Hence, agricultural producers may only experience small overall percentage changes in revenue, if reductions in yield are offset by increases in market price. For the energy sector, regulated utilities may be able to pass price increases through to consumers, whereas the revenue of unregulated utilities is largely determined by market forces, and supply and demand will influence price. Therefore, as a simplifying assumption, changes in price are not accounted for, and only changes in productivity are considered.[1]

The impacts of future extreme events on downtime and production losses are translated into changes in revenue. Changes in the frequencies of extreme events in the future compared to the present-day are combined with empirical data on production losses, to evaluate corresponding impacts on future revenues. Again, percentage changes in production are assumed to translate into equivalent percentage changes in annual revenue.

Changes in cost of goods sold following extreme events are inferred from changes in revenue. Empirical evidence and models of demand surge from the catastrophe risk modeling experts, RMS, provide data on the relationships between changes in revenue and COGS for industry sub-sectors following an extreme event (see Box 2.5). The relationships are approximately linear and are assumed to apply to all extreme events. They show that, while revenues fall due to an extreme event, costs tend to increase. This 'demand surge' effect on costs arises when demands for reconstruction materials, labor, equipment, etc. outstrip supplies.

1. The transition risk scenarios provide data on changes in price of electricity and fuel due to transition risk drivers (see the first report in this series by UNEP FI, Oliver Wyman and Mercer 'Extending our horizons: Assessing credit risk and opportunity in a changing climate: Outputs of a working group of 16 banks piloting the TCFD Recommendations'). However, these data are not applicable to physical risk, where the drivers of changes in price relate to other factors, such as availability of water for power production, etc.

BOX 2.5: Evaluating relationships between changes in revenue and COGS

Authored by Laurence Carter, RMS

RMS developed a 'Drought Stress Testing Tool' for use by financial institutions.[14] As part of the tool development, RMS developed a series of revenue factors and cost of goods sold (COGS) factors. These relate the level of drought hazard experienced at a location to the impact to revenue reduction and costs experienced by a company operating in that location. These factors were developed for all industry sub-sectors, regions and drought scenarios contained within the tool. The value set for each factor is dependent on the level of drought experienced in the region, the industry sub-sector, the types of water abstraction sources in the region and the transportation channel through which the company likely receives water.

Although the revenue and COGS factors were initially developed independently of each other, they are both correlated to the level of drought experienced. There are negatively correlated relationships between the revenue factors and the COGS factors. These relationships are found to be approximately linear.

The parameters of the linear relationships depend on the industry being analyzed. For example, under extreme drought conditions an agricultural business producing crops could experience severe drops in revenue without incurring much additional cost. However, an oil company might experience large changes in extraction costs together with decreasing revenue under the same conditions. This variability is reflected in the coefficients used to define the linear relationships for each industry sub-sector.

The assessments do not take account of actions that borrowers may undertake to manage physical climate risks. The studies used to derive climate change impacts on sector productivity do not take account of adaptation. They may therefore overestimate net impacts, where adaptation actions by borrowers would help to reduce climate-related impacts on revenues and COGS. In this regard, suggested improvements to future iterations of the methodology are discussed in Chapter 5.

BOX 2.6: Insights from a Working Group bank - Managing climate risk with agricultural clients

Understanding the impacts of physical climate risk on customers, particularly those in climate-sensitive sectors like agriculture, is critical to understanding future possible changes in customer credit risk profiles and lending portfolios. Having easy-to-access, easy-to-understand, timely and accurate weather and climate information is vital for farmers and of importance to banks, so we can understand the risks facing our customers.

On-farm drought preparedness and adaptation activities are increasingly important, allowing farmers to better manage their operations through droughts and recover quickly afterwards, particularly as climate projections under a 4°C or business-as-usual (BAU) climate scenario indicate drought severity and frequency are almost certain to increase.

During drought, financial support is often provided by governments to help sectors such as agriculture. This can include financial counseling and grants for specific water efficiency measures. Banks will generally be willing to provide assistance in terms of debt restructuring and on occasion, additional lending to help farmers during a drought. As a result of drought conditions, many farmers will experience significant variability in farm productivity and performance, but in most instances a well-managed agricultural customer is likely to recover and return to profitable trading with sustainable debt levels. Generally, the impact of severe drought on credit ratings will not appear immediately, but can be delayed for eighteen months or longer as financial results crystalize.

2.4.3. Determining changes in probability of default

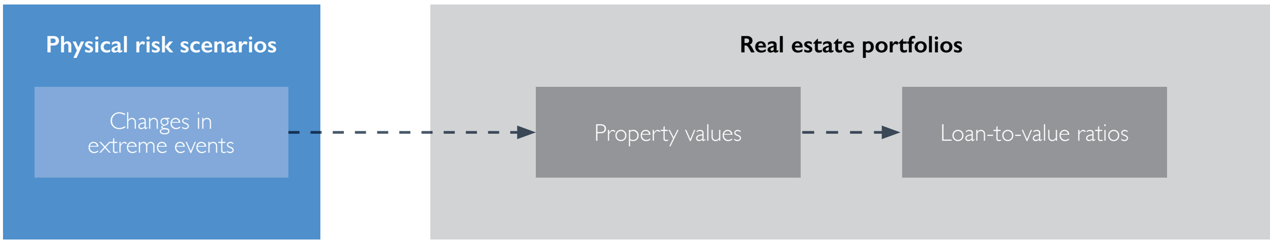
Estimates of changes in revenues and COGS are used to evaluate changes in credit risk for individual borrowers and sector portfolios. This process involves stressing factors/ratios in the bank's rating models that have revenue and cost components and calculating revised risk grades across the portfolio. These calculations are performed for each time period (2020s and 2040s) and climate scenario (2°C and 4°C). A sample of borrowers that are representative of a sector portfolio can be assessed individually, and the findings extrapolated to the whole portfolio. It may also be feasible to analyze whole sector portfolios.

All non-revenue and non-COGS related factors and ratios are held constant in the rating model. It is recognized that other factors in rating models, such as borrower's management (e.g. regarding management of physical climate risks), could be modified. For practical reasons, these factors are left unchanged.

2.5. REAL ESTATE: CLIMATE CHANGE IMPACTS ON LOAN-TO-VALUE RATIOS

The real estate methodology assesses potential changes in property values and loan-to-value ratios due to extreme weather events (see Figure 2.6). It is applicable to retail mortgages and income-producing real estate (IPRE). For IPRE, as a simplifying assumption, the impacts of extreme events on borrower revenues (e.g. loss of rental income) are not factored into the assessment. Other types of commercial real estate lending are not covered by the methodology, as these borrowers have other sources of income which complicates the analysis.

Figure 2.6: Overview of the physical climate risk methodology for assessing changes in loan-to-value ratios for real estate



2.5.1. Estimating impacts of extreme events on property values

According to empirical evidence, property values can be affected by extreme weather events. Published research on hurricanes (which can lead to wind damage and flooding) shows the value of affected homes declines in their aftermath compared to average market prices, typically over a four-year period.[15-16] Literature also points to a similar trend for properties affected by wildfires, with a fall in sale prices in subsequent years.[17]

A range of factors interplay for property value and extreme events, including property owners' perceptions of risk, and insurance pricing and availability. The delineation of 'at-risk' zones, for instance through the publication of updated flood risk maps by government agencies,[18] can negatively impact on property value as beliefs around the 'riskiness' of the location change, and because increased insurance premiums may be expected.[19] Further, residents' risk preferences play a part in their decision to live in places that they deem to be attractive (for example coastal areas or green spaces) even though these might be at higher risk, so long as they have so far been spared.[20] Unaffected properties can even see increases in their value compared to affected properties in the same area. The same applies to affected properties that have undergone maintenance and enhancement works (e.g. to improve their flood-resilience) following damage from an extreme event.[21]

Drawing on empirical evidence, the real estate methodology provides high-level estimates of changes in property values due to extreme events. Evidence indicates that experience of extreme events can reduce property values by between 5% and 20%. Information is not available on potential updates to flood risk maps / zones, or insurance price or availability, so these factors are excluded from the methodology. Property values are highly location-specific and are influenced by many factors, such as market conditions, location, property size and rental incomes. Banks can refine the high-level estimates by undertaking their own analysis of how past extreme events have affected property values in their portfolios (see Box 2.7).

It is assumed that no change in property values will occur if a property is not at risk from extreme events; other drivers of change in future property values are excluded from the analysis. As a simplifying assumption, other factors are held constant as per today's conditions. Moreover, it is assumed that there is no adaptation of existing building stock or changes in weather-related design standards for new buildings.

BOX 2.7: Developing portfolio-specific estimates of changes in property values

Banks should consider undertaking their own research to correlate observed extreme events with changes in loan-to-value ratios in their portfolio. The high-level estimates of changes in property values applied in the pilot project are based on empirical evidence of extreme weather events which affected property in specific locations. However, differences in property markets will affect the way that property value responds to extreme events. As such, using evidence from past extreme events specific to banks' own portfolios will help to develop a more accurate assessment. This is further discussed in Chapter 5.

2.5.2. Determining changes in loan-to-value ratios

The high-level estimates of changes in property values are applied to properties that are identified to be at risk of future extreme events, and revised LTV ratios are calculated. Data on future return periods for extreme events under 2°C and 4°C scenarios (Section 2.3) are converted into 'encounter probabilities' – the chances of properties experiencing extreme events over the average remaining mortgage term for the portfolio. Banks will calculate the average remaining terms specific to their retail and IPRE portfolios. The encounter probabilities for each extreme event are then multiplied by the high-level estimates of changes in property values, and the results are aggregated, to calculate the 'risk to property value' for each climate scenario and time period, across all relevant extreme events. Finally, the original property values are adjusted by the 'risk to property value', to arrive at revised LTV ratios.

3. OPERATIONALIZING THE APPROACH: LESSONS LEARNED FROM BANK PILOTING

During the pilot project, each bank in the Working Group has co-developed and trialed at least one of the physical risk methodologies. This Chapter presents the results, findings and lessons learned from a number of the banks. Some of the case studies are directly attributed to individual banks, whereas others have been anonymized.

The banks recognize a number of benefits from trialing the physical risk methodologies. These include bringing together teams of experts from across the bank to look at climate change risk in a more multi-faceted and cross-cutting way, and developing a preliminary understanding of the potential risks in their lending portfolios. These informational, institutional and capacity building activities will help the banks move forward to develop more robust and evidence-based responses to the risks that climate change poses.

The banks have also faced a number of challenges during the piloting of the physical risk methodologies. These include collation and processing of bank-level data prior to assessment, labor intensive data analysis and insufficient granularity or lack of data for some locations and climate parameters. A number of solutions have been identified to overcome these challenges and are explored in detail in Chapter 5.

3.1. BANK #1 CASE STUDY: AGRICULTURE

3.1.1. Introduction

Piloting a scenario-based stress test assessment of agricultural physical risk involved collaboration between relevant modelers, analysts and subject matter credit experts. The first step was to define what was meant by 'agriculture'. This Bank used ISIC classifications for Agriculture and Forestry, i.e. primary production only.

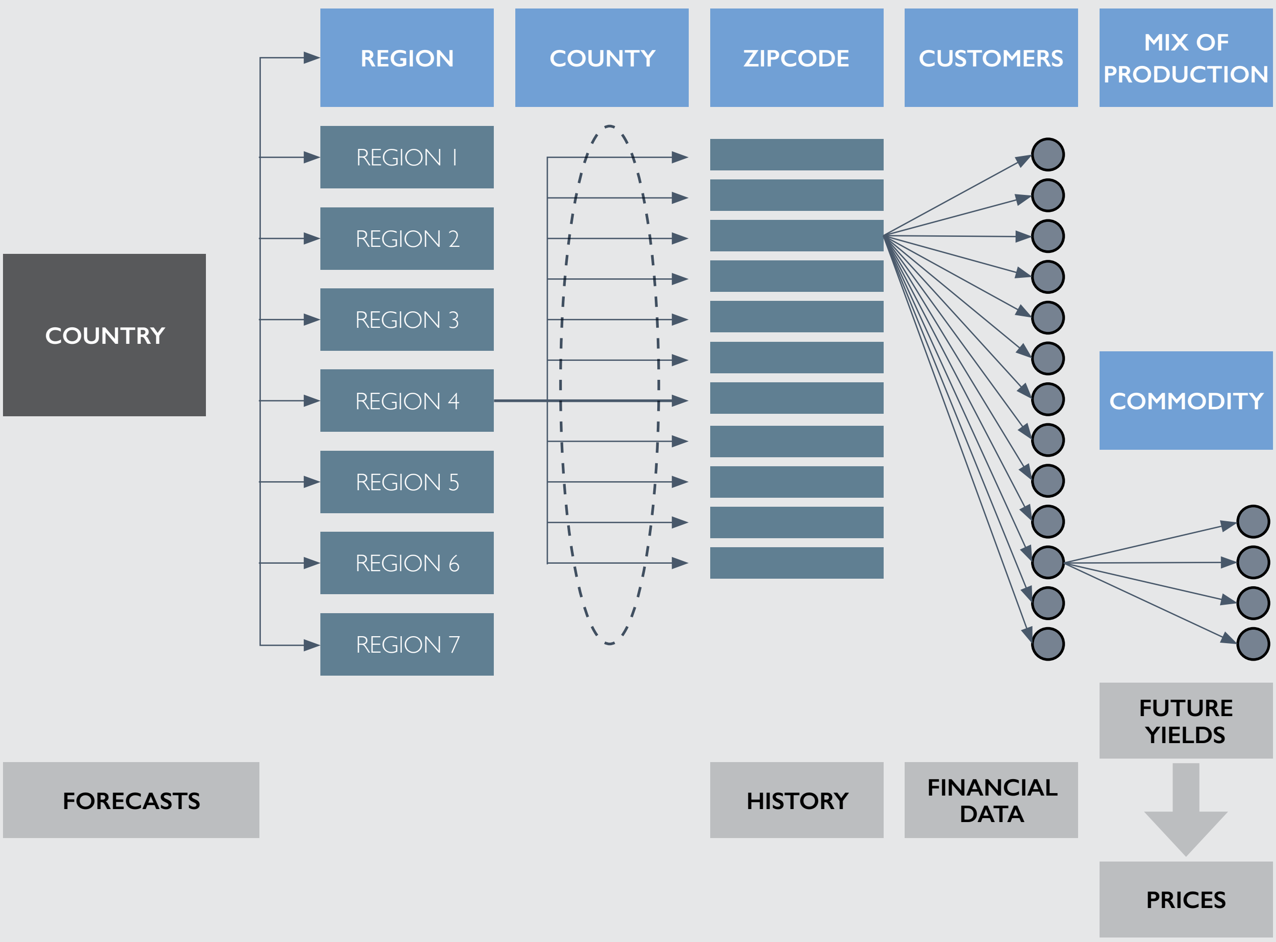
The objective of the analysis was to determine the change in probability of default (PD) of the overall agricultural portfolio, resulting from the impacts of incremental climate change on PD, plus the impact of increasing frequency of extreme events.

A feature of the agriculture industry is that revenues are inherently volatile because commodity prices are often determined in a global market, and weather conditions through the season are the main determinant of production yield. Thus, to explain the future climate risk impact on agriculture, it was necessary to recognize that an element of weather and climate risk has been an ever-present factor in agriculture that is already factored into the baseline portfolio PD to be stress tested.

3.1.2. Analysis of a representative sample of borrowers

This Bank's agriculture portfolio covers a large geography and diverse commodities. As detailed crop and climate data are only currently available at a large spatial scale, the stress testing was conducted at whole of portfolio level, based on a representative sample of both farming activity and geographic location. The sources of data to complete the analysis included customer level and commodity level information, through to climate change impacts being at large-scale country level (see Figure 3.1). Specialist review was required in all steps to determine elements that were representative of the portfolio.

Figure 3.1: Data required for stress test analysis held at varying spatial scales

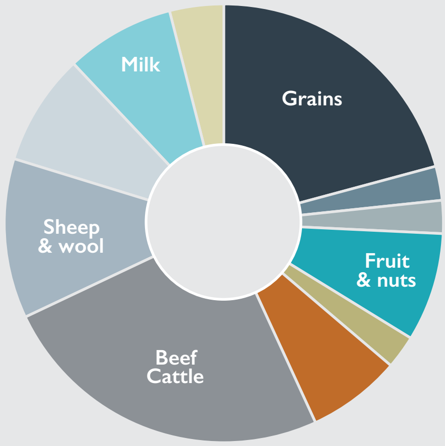


The following steps were taken to derive a representative sample:

- Determine the weighted average PD of the productive loan portfolio;
- Review the break-up of this portfolio by commodity/crop types and weighting of these within the portfolio. Determine how many customers per commodity/crop type to select based on this weighting – minimum of 20 in total. Include commodity/crop types that carry a portfolio weighting greater than 10% (see Figure 3.2);
- Within each commodity/crop type, determine distribution of the total portfolio by geography; and
- Within each commodity/crop type, determine the typical debt of a customer within bands.

Figure 3.2: Break-up of loan portfolio by commodity/crop type to determine representative sample size

EXPOSURE BY COMMODITY / CROP TYPE	TOP 5 COMMODITY / CROP TYPE	FOR EACH COMMODITY / CROP TYPE:



	#Borrowers
Beef Cattle	7
Grains	5
Sheep & wool	4
Fruit & nuts	2
Milk	2
Total	20

- Determine distribution by region
- Determine typical customer by rating and debt size

3.1.3. Stress testing the sample

The physical risk methodology for incremental climate change assumes that impacts would result in changes in production for the particular location and changes in price as a result of global supply and demand. The methodology for extreme climate events assumes a change in the frequency of these events, with each event causing a one-off impact on revenue. Sensitivities include an assessment of the probability of and impact on revenue from the increase in frequency.

The projected changes in production and price per commodity for incremental climate change and the increases in frequency of extreme events were supplied by Acclimatise from their research of peer-reviewed scientific papers.

For each customer, historical data and projected changes were determined for each of their property locations and the impact of both incremental change and extreme events were considered.

The following data sources were used to determine baseline extreme event conditions:

- Storm/cyclone/flooding, fire – UNEP Global Risk Data Platform[m]
- Extreme heat – GFDRR Think Hazard[n]
- Drought – Princeton Climate Analytics.

Swiss Re's CatNet®[o] and Munich Re's NatCatSERVICE[p] are also good sources of data at a coordinate level spatial scale.

m. preview.grid.unep.ch/index.php?preview=map&lang=eng
n. thinkhazard.org/en/
o. www.swissre.com/clients/client_tools/about_catnet.html
p. www.munichre.com/en/reinsurance/business/non-life/natcatservice/index.html

3.1.4. Segment stress sensitivities

Having determined the impact on revenue for a customer, Bank 1 then looked at how this would affect the variables used to calculate the customer PD from their rating model. Bank 1 held all other factors constant, including farming costs. In the event of reduced production, farming enterprises do adjust costs, however there were no reliable data with which to stress test, and the physical risk methodology excludes adaptation. The financial ratios adjusted when completing the sensitivity were those connected with revenue and profitability. Other factors were examined and any that would change as a result of an extreme event were adjusted – such as funding increases to support lost production revenue or rescheduling of loan amortization.

Extreme event stress test sensitivities included loss of crops and livestock from extreme events. However, losses from damage to plant, equipment and infrastructure were excluded, as these could be claimed on the customer's insurance cover that is usually required by the Bank as part of loan approvals.

3.1.5. Sector portfolio results / findings

Incremental change impacted the representative customer revenue by -6% to -12% under the 2020s 2°C and 4°C scenarios and reached -12% to -22% under the 2040s 4°C scenario. The revenue impact of an increase in frequency of extreme events added circa 1% impact on revenue, based on cumulative events that could occur over a 12 month period.

Table 3.1 shows the result of application of the above revenue impact, with the PD profile deteriorating under the 2020s 2°C and 4°C scenario and the 2040s 2°C scenario, however the portfolio average rating remained stable as per baseline. Under the 2040s 4°C scenario, the PD increased to a greater extent – between 1.1x to 1.5x, and average portfolio rating deteriorates by a one notch downgrade.

Table 3.1: Physical risk stress test analysis outputs for representative sample group. PD notching equivalent to rating agency alpha numeric scales.

INDUSTRY	2020s SCENARIO	2040s SCENARIO	
	2°C & 4°C	2°C	4°C
Mixed farming	1 notch	1 notch	2 notches
Grain	<1 notch	<1 notch	1 notch
Cotton	1 notch	1 notch	2 notches
Horticulture	1 notch	1 notch	1 notch
Beef farming	<1 notch	<1 notch	<1 notch
Dairy farming	1 notch	1 notch	1 notch
Others	1 notch	1 notch	2 notches
Total portfolio	**<1 notch**	**<1 notch**	**1 notch**

Note: Where customer's PD profile deteriorates across the stress test scenarios but the movement is insufficient to shift the rating band by a notch, '<1 notch' is recorded above.

Portfolio calibration is achieved by applying the PD impact from the representative sample to remaining customers within the corresponding segment. For segments where reliable data on the underlying portfolio breakdown are not available, for example mixed farming, Bank 1 assumed 50% livestock and 50% cropping. This was also applied to the balance of the portfolio described as "Other".

3.1.6. Lessons learned, challenges and the way forward

Agriculture is a generally resilient industry, and usually recovers relatively quickly from one extreme event. Scientific research indicates that these extreme events are projected to increase in both frequency and severity. The ability of agricultural enterprises to absorb the costs and lower levels of production from repeated extreme events such as storms, floods and drought is not known. Research suggests that annual revenue impacts of up to 50% per event are possible, and more than one event in a 12 month period is possible.

Benefits

The exercise has connected the Bank with leaders in the scientific community and government agencies to advance the discussion on the impact of climate risk on domestic food security.

The analysis is a good first step to facilitate further conversation with the Bank's customers about climate change risk and opportunities.

Challenges

The stress test did not factor in adaptation; however agriculture is a good example of how practice changes with climate, and commodities grown change with global demand and the price determined by supply.

A well-diversified and geographically spread portfolio also disguises the impact an extreme event can have on an individual customer or geographic location. Banks that have concentrations in particular industries or geographic locations may be more heavily impacted.

Uncertainties and gaps

Numerous data gaps exist from historical records of extreme events, through to projections of future change being at a sufficiently granular spatial scale to allow for meaningful analysis. A benefit of the exercise was to make connections with the researchers who can do this work, and now there is an industry demand for the information.

Improvements for future iterations

As data becomes available at more granular spatial scales, and also with smaller banding of return periods, impacts can be assessed more robustly based on customer location, both for climate impacts and also production impacts. For example, whilst flooding history may be known for a customer's farm, production impacts are generally expressed at national level. The current modeling and data available also appears to underestimate the impact of extreme events, particularly flash droughts[q] and long-term droughts. Further research in this area would also be useful.

q. Rapid-onset droughts. For further details see: journals.ametsoc.org/doi/abs/10.1175/BAMS-D-17-0149.1

3.2. ITAU UNIBANCO CASE STUDY: PHYSICAL RISK IN THE AGRICULTURE SECTOR

3.2.1. Introduction

In order to disclose recent developments in this field, this case study demonstrates the practical application by Itaú Unibanco of the pilot methodology for measuring and assessing physical risks associated with climate change. This methodology was developed in an international working group coordinated by UNEP FI that involved 16 banks working with Acclimatise.

3.2.2. Methodology

This methodology was specifically developed for the physical risk associated with climate change in the agriculture sector.

The hypothesis adopted by the methodology is that there are two ways in which agricultural activity can be impacted by climate change.

First, through incremental changes in temperature, precipitation patterns and related variables that will occur gradually over the years. The scale of this impact is global and therefore affects the financial health of agricultural enterprises by changing the production and the respective price of the good. In this type of risk, each crop will be impacted differently, depending on the region. For example, sugarcane production in São Paulo will be affected differently from cane production in Goiás.

Climate change is also changing the frequency and intensity of extreme events. There were five types of extreme events selected for the pilot project: cyclones, drought, extreme heat, floods and wildfires. All of them have a local impact scale and therefore affect the financial health of the companies in the sector by changing the quantity produced and the cost of production. In this type of risk, each crop in the same region should be impacted differently, depending on its capacity to cope with the extremes. For example, a drought in São Paulo will affect corn production more than eucalyptus production.

In a simplified way, the tool developed consists of 4 steps:

1. Establishment of climatic scenarios. In this case, two climatic scenarios (2°C and 4°C) were considered and two horizons (the 2020s, centered on the year 2025 and the 2040s, centered on 2045) were evaluated.
2. Bibliographical verification of how some indicators of interest (production, price, cost) will behave in the face of incremental and extreme events risks. It is expected that there are different behaviors, according to the scenario, activity and regions studied;
3. Evaluation of how the credit quality of a sample of companies is affected by the change of indicators of interest. That is, a stress test exercise that proposes the variation of the studied factors while keeping all other factors constant;
4. Extrapolation of the results of this sample to the entire portfolio of the bank in the agricultural sector.

3.2.3. Application of the methodology

In order to conduct the work, Itaú required the involvement of several areas of the bank so that all the necessary expertise could be filled out:

1. Socioenvironmental risk area, responsible for validating the methodology and coordinating other areas;
2. Sustainability, responsible for engagement in the work group;
3. Portfolio management area, responsible for data collection;
4. Credit area, responsible for evaluating the impacts on clients' credit;
5. Commercial area, responsible for technical aspects of the agricultural sector.

For the application of this methodology, Itaú Unibanco selected a portfolio with about 130 rural producer clients in the bank's corporate sector. This portfolio represents a risk of approximately R$ 4 billion concentrated in short term operations.

All the activities of these clients are in Brazil, especially in the states of Mato Grosso, Minas Gerais, Bahia, São Paulo, Tocantins and Goiás.

The activities of these clients are diverse, though the most important are the production of soybeans, corn, sugarcane and livestock. Importantly, most customers have more than one activity.

For the sample selection of clients for individual analysis, we divided the portfolio described above into 2 groups. The first group is customers with a comfortable credit quality. The second group was represented by clients who had some kind of financial difficulty. The criteria for group division was subjective, based on credit specialist analysis.

We selected a sample of 14 clients (10 clients from group 1 and 4 clients from group 2), using the criteria listed below so that a representative sample could be obtained from the portfolio of 130 clients selected for this study:

1. Customers that represent the largest credit exposure.
2. Customers that represent the most relevant states in the portfolio, if possible all.
3. Customers who represent the most relevant crops in the portfolio, if possible all.
4. If possible, clients with different credit qualities (different ratings).

Table 3.2 shows the customer selection information for the sample.

Table 3.2. Customer characteristics selected for the sample

CLIENT	RATING (S&P)	RISK (R$ MM)	NUMBER OF STATES	NUMBER OF CROP TYPES
Client 1	BBB	391.8	1	5
Client 2	BB+	129.3	1	3
Client 3	BBB	115.5	1	2
Client 4	BB-	112.3	1	2
Client 5	BB	108.7	1	4
Client 6	BB-	107.6	1	3
Client 7	BB	84.1	1	3
Client 8	B	55.7	2	4
Client 9	BB-	55.3	1	2
Client 10	B	44.1	3	3
Client 11	BB-	42.0	1	4
Client 12	BB-	41.2	4	4
Client 13	B	39.5	1	5
Client 14	B	17.2	2	6

In this case study, only the evaluation of one scenario (4°C) and time horizon (2040s), which would represent the greatest possible impact of the physical risks among the scenarios and horizons covered by the methodology, will be demonstrated.

In the scenario and horizon chosen, we performed the calculations of how physical risk impacts the various financial variables defined according to the methodology.

Table 3.3 shows the figures for incremental risk and Table 3.4 shows the numbers related to the risk of extreme events.

Table 3.3. Impact of incremental climate change risk on the financial variables of the sample of agricultural sector clients for the 2040s 4°C scenario compared to the present-day (baseline)

CLIENT	REVENUE CHANGE (%)
Client 1	-12
Client 2	-4
Client 3	22
Client 4	-16
Client 5	-14
Client 6	-13
Client 7	-3
Client 8	-2
Client 9	-4
Client 10	-2
Client 11	-10
Client 12	-8
Client 13	-11
Client 14	-8

Table 3.4. Impact of the risk of extreme events on the financial variables of the sample of agricultural sector clients for the 2040s 4°C scenario compared to the present-day (baseline)

CLIENT	REVENUE CHANGE (%)	COST CHANGE (%)
Client 1	-3.4	0.4
Client 2	-3.5	0.4
Client 3	3	-0.4
Client 4	3	-0.4
Client 5	-3.5	0.4
Client 6	3.5	-0.4
Client 7	-3.5	0.4
Client 8	-0.2	0
Client 9	-1.3	0.2
Client 10	0.6	-0.1
Client 11	1.1	-0.1
Client 12	-2.3	0.3
Client 13	-3.4	0.4
Client 14	3.3	-0.4

To obtain the data in Table 3.3, it was necessary to make some decisions, which are highlighted as follows: i) whenever a range of values was provided for a parameter, we chose the figure that would provide the worst case; ii) in the absence of climate change parameters for some agricultural activities (crop types), estimates were adopted based on the judgment of experts; iii) when there were no data on incremental climate change impacts on price for some agricultural activities, it was conservatively assumed that there was zero change in price.

Likewise, in order to get the data in Table 3.4, some observations are worth making about the five extreme events considered. Cyclones are not foreseen in Brazil, so their contribution is not considered in the analysis. In relation to flood events, only a small area of Brazil is susceptible to flooding, so its contribution is close to zero. It is also worth noting that in order to calculate the flood effect, an estimation of the distribution of the production areas was made, since we did not have the exact locations for each client. Another effect whose impact tends to zero is associated with wildfires, since the damages associated with this event are low and climate change does not change wildfire frequency much in our study areas. On the other hand, we have the climatic effect associated with drought as the most relevant factor identified. For this extreme event, the present case study considered, given the Brazilian reality, that a change in the frequency of droughts lasting one month or more may already result in a decrease in production.

3.2.4. Results

As explained earlier, the sum of the impacts of incremental risk (Table 3.3) and extreme event risk (Table 3.4) generates the total impact of physical risk. To evaluate how this total impact influenced the ratings of the 14 companies in the sample, the stress test technique was used. That is, a balance sheet was projected from the actual balance sheet changed only by the impacts resulting from the total physical risk. With this climate adjusted balanced sheet, you can calculate a projected rating and compare it with the actual rating. The qualitative result obtained in the sample of clients is in Table 3.5.

Table 3.5. Qualitative results obtained by client

CLIENT	QUALITATIVE IMPACT
Client 1	Negative and Medium
Client 2	Neutral
Client 3	Neutral
Client 4	Negative and Medium
Client 5	Negative and Medium
Client 6	Neutral
Client 7	Neutral
Client 8	Neutral
Client 9	Neutral
Client 10	Neutral
Client 11	Neutral
Client 12	Negative and Medium
Client 13	Negative and Medium
Client 14	Neutral

Since this sample represents all the approximately 130 clients of the selected portfolio, the results obtained can be extrapolated. Thus, considering the characteristics of the portfolio and the methodological assumptions, it can be inferred that the physical risk associated with climate change has a low downgrade potential overall in the agricultural sector portfolio.

Specifically, we can note that lower negative impacts of revenue and cost do not affect rating, but after a certain level of impact, there is a large rating variation. On the other hand, no client has benefited from climate change. Still, the results do not indicate that there is a variation of impact according to the client's starting rating.

Also, it can be clearly seen, comparing Table 3.3 and Table 3.4, that incremental climate change risk has a greater impact on the financials of the companies studied than the risk associated with extreme events.

3.2.5. Lessons learned, challenges and the way forward

The present case study proves that the main objective of the methodology was fulfilled, since it was possible to begin to quantify the physical risk associated with climate change for the agriculture sector portfolio.

The great benefit from this exercise is that with these figures it is possible to start adequate long-term planning that optimizes the resources available for risk management.

The result obtained is not worrying because it has not presented a great potential credit risk, besides being a stress test exercise for a long-term horizon. It should also be noted that the study horizon is much larger than the average term of the portfolio, that is, no short-term decisions are necessary. Nevertheless, it gives us the opportunity to better plan the future credit portfolio.

The methodology is clear to pilot. Thus, with adequate resources and commitment, we found that there is no great challenge in incorporating this methodology into the activities of the bank.

However, there were limitations and gaps in the methodology that will need to be worked on to promote continuous improvement. Among the main limitations and shortcomings, we highlight the following five:

1. Due to lack of data, the methodology did not consider that climate change can have an impact on client investment. This premise, although a necessary assumption to move forward with the methodology, does not seem to be reasonable in reality, since companies usually invest to minimize their risks.
2. The extrapolation of results from the sample to the entire portfolio uses a direct extrapolation technique. Although it is satisfactory, we recommend the adoption of a more robust technique that distributes impacts in a portfolio.
3. According to the methodology, impacts of extreme events are evaluated separately and then summed. However, the methodology does not consider additional impacts in case two extreme events occur at the same time. For example, impacts of a wildfire could be greater when occurring at the same time as a drought than if occurring alone.
4. The analysis associated with some extreme events depends on information about the location of the clients' activities. For this case study, we used some approximation and not very accurate data which generates an inaccurate result. In this way, it is necessary to invest in the capture of this type of information.
5. There is still a great deal of divergence of climate change impact data. Since the result could vary greatly depending on the source of information to be adopted. In this way, it is necessary to invest in the generation of new more precise and convergent information.

3.3. TD BANK GROUP CASE STUDY: TD AND BLOOMBERG COLLABORATE ON TESTING THE USE OF GEOSPATIAL MAPPING FOR PHYSICAL RISK ASSESSMENT

This case study highlights an innovative geospatial solution for assessing physical risks of climate change (from both incremental changes and extreme weather events) on borrower credit ratings within a bank's lending portfolio. The approach was developed by TD Bank Group (TD), Bloomberg and Acclimatise, and is applied to the physical risk assessment methodology from Acclimatise as part of the UN Environment Finance Initiative (UNEP FI) pilot study. Although this solution can be used by companies within any sector and geography (provided that data are available), for the purposes of this study, the analysis was performed on a sample of borrowers within the power and utilities sector in North America. Use of a geospatial tool such as Bloomberg MAPS provides efficiencies through its ability to overlay and analyze multiple datasets – bringing together geographic data on projected climate change with locations of borrowers' facilities and corresponding financial and production data. Bloomberg MAPS pulls input data and information directly from the Bloomberg network.

3.3.1. Scope

For this case study, a sample of 20 borrowers from TD's North American power and utilities portfolio was analyzed under three climate scenarios:[r] 2020s, 2°C & 4°C; 2040s, 2°C; and 2040s, 4°C. The borrower sample was selected based on:

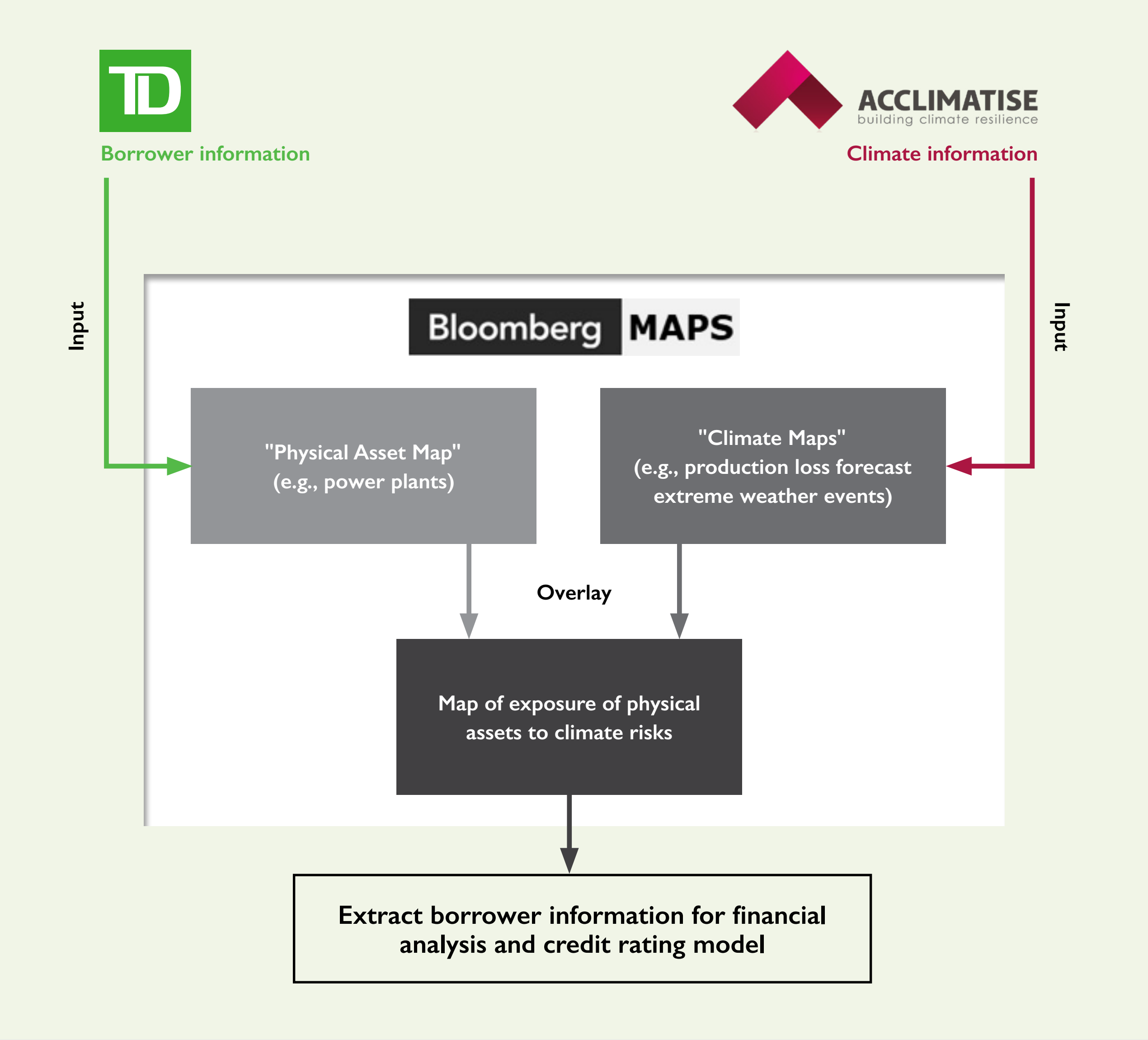
1. **Amount of exposure:** total sample represents approximately half of the total exposure at default for the power and utilities portfolio.
2. **Location of physical assets:** sample includes borrowers' facilities (i.e., hydroelectric and thermal power plants) covering multiple geographic regions across North America.
3. **Credit ratings:** the range of credit ratings is reflective of the power and utilities portfolio.

3.3.2. Assessment method: Bloomberg MAPS

Figure 3.3 provides an overview of the Bloomberg MAPS approach to assessing physical risk. The physical impact of climate change on power production was assessed by layering a map of power plant locations, "Physical Asset Map", with a "Climate Map" of observed extreme weather events (including cyclones, floods, extreme heat, water stress and wildfires), and a dataset representing expected changes in annual power production capacity due to incremental climate change impacts. Facility information was extracted and aggregated to calculate the expected change to the borrowers' revenue and cost of goods sold (COGS), which are key inputs to credit rating models.

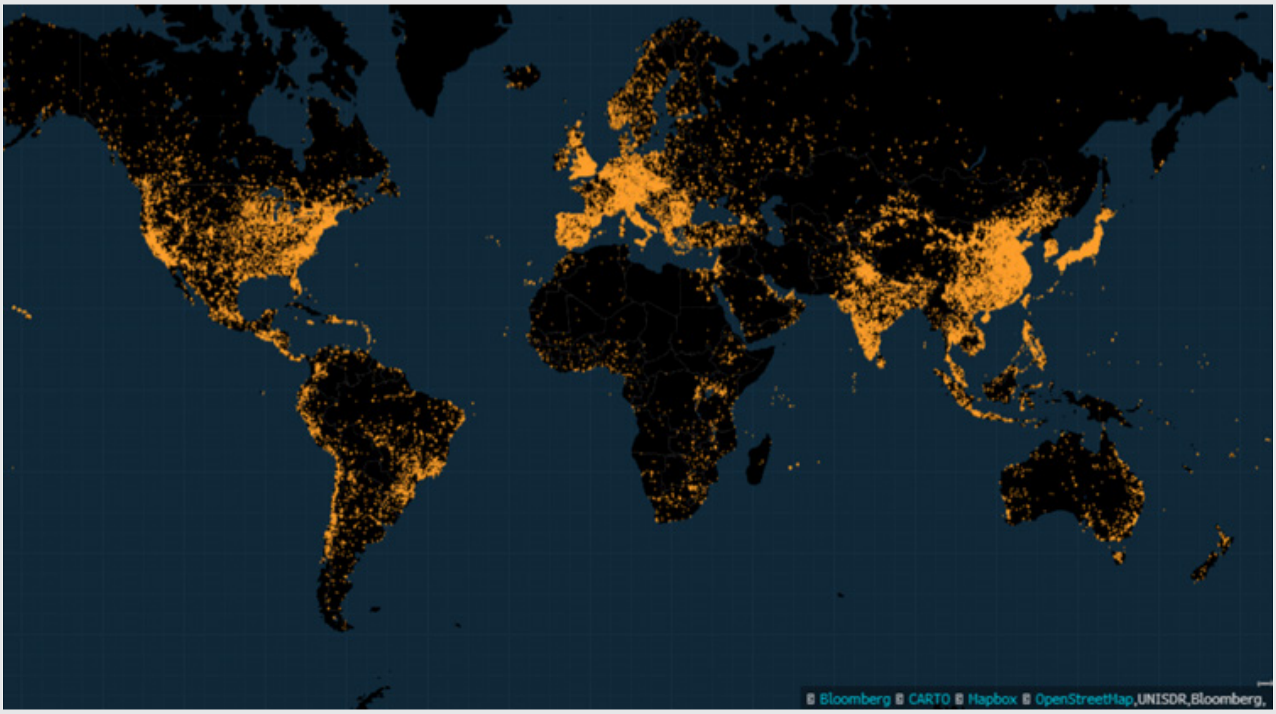
r. Scenarios of change in global average temperature by 2100 relative to the pre-industrial era.

Figure 3.3: Bloomberg MAPS approach process diagram



The figures below illustrate how the Bloomberg MAPS tool can be used, using different examples and timeframes. Figure 3.4 to Figure 3.6 demonstrate the steps outlined in Figure 3.3 based on a 1:50 year cyclone risk. Figure 3.7 to Figure 3.9 provide additional examples of how the tool can overlay datasets using extreme heat risk exposure, along with incremental impacts to production due to 2°C and 4°C temperature rises.

Figure 3.4: Location of global power plants (Physical Asset Map)



Note: *Figure 3.4 to Figure 3.9 show all power plants globally, not TD's portfolio of borrowers.*

Figure 3.5: Present-day 1:50 year cyclone risk (Climate Map)

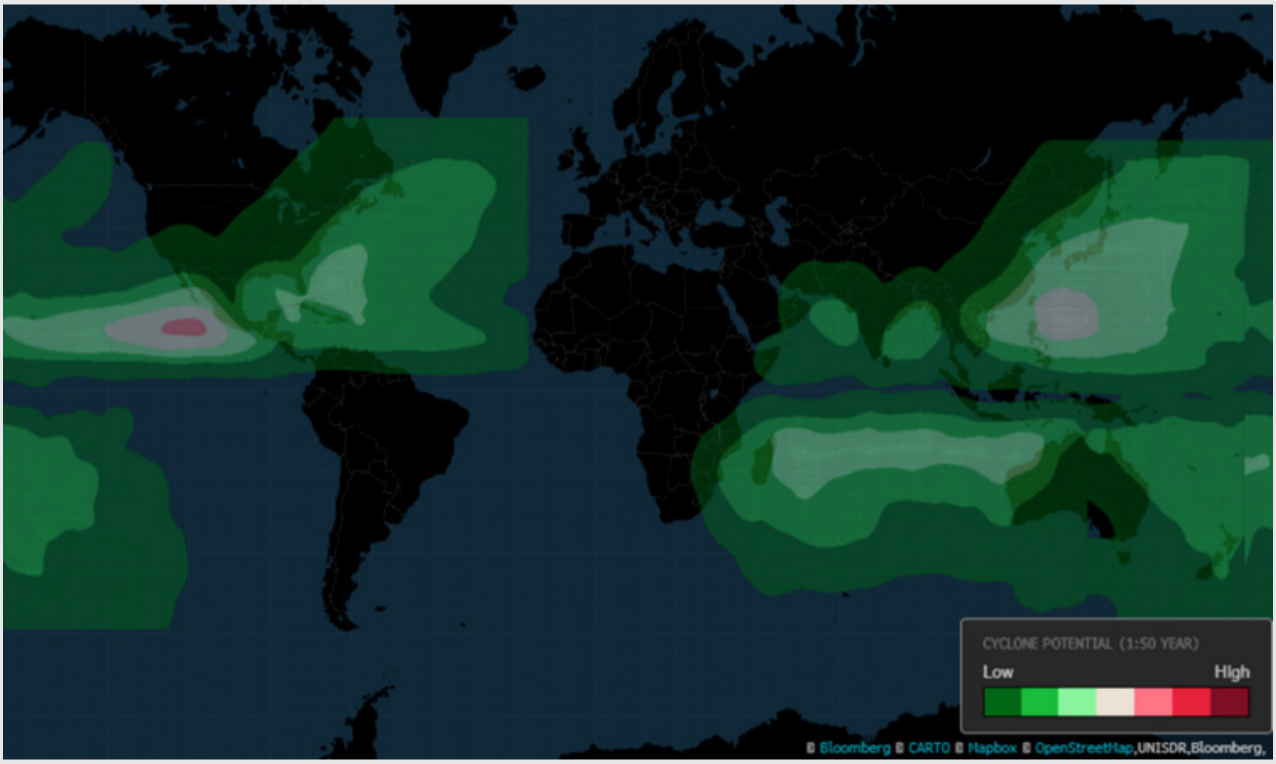


Figure 3.6: Overlay – Exposure of global power plants to present-day 1:50 year cyclone risk *(Exposure of Physical Assets to Climate Risks)*

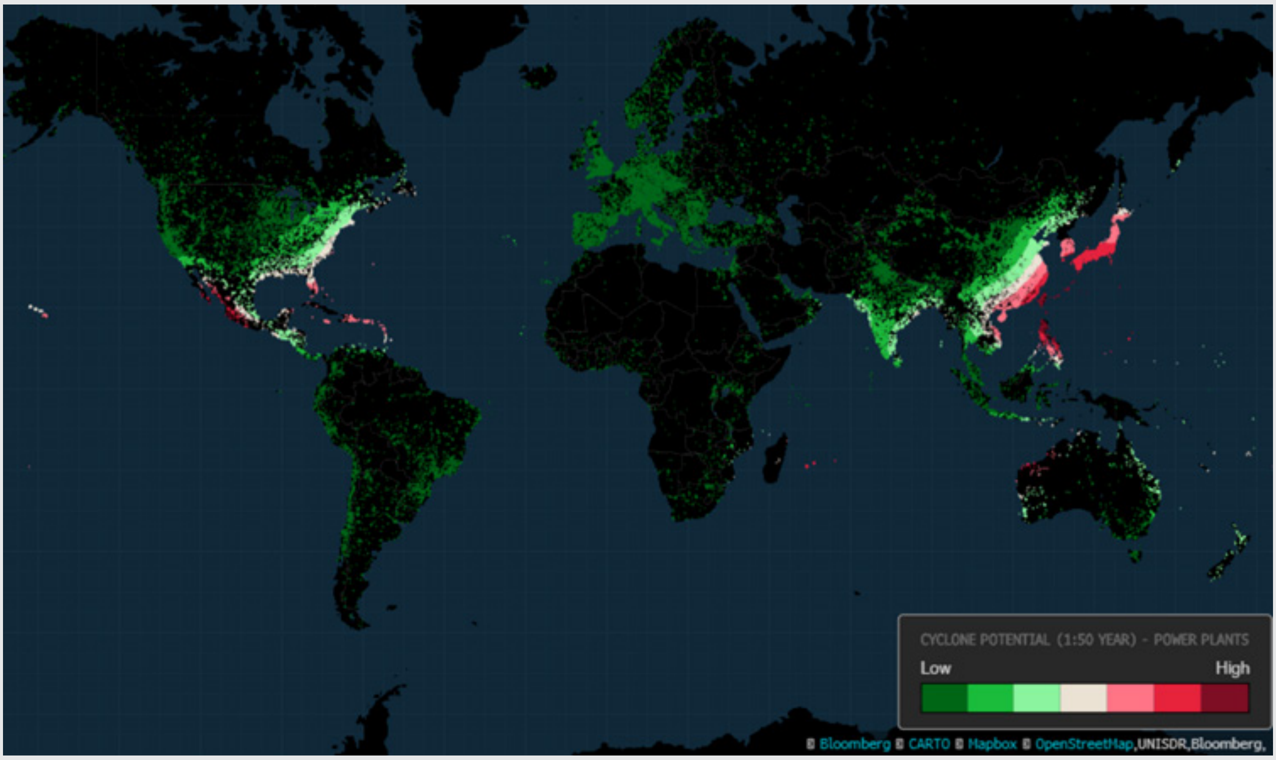


Figure 3.7: Overlay – Exposure of global power plants to present-day 1:100 year extreme heat risk *(Exposure of Physical Assets to Climate Risks)*

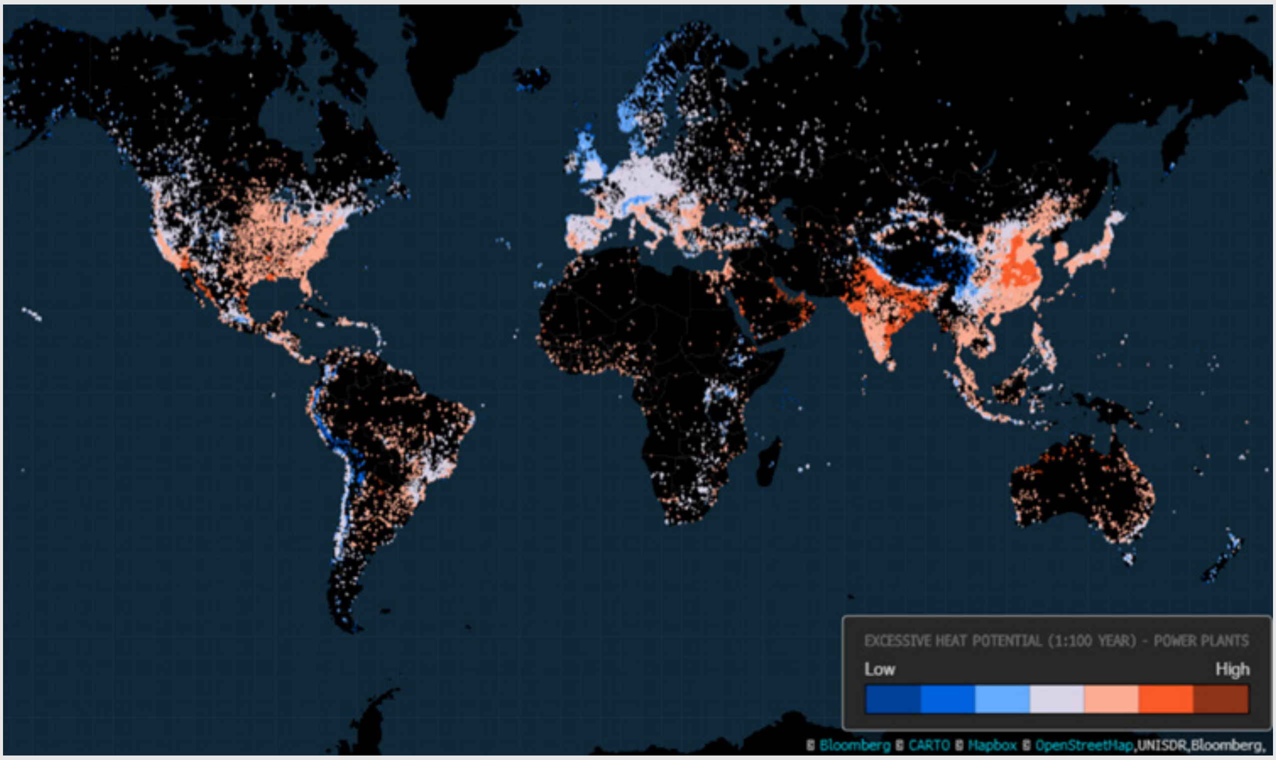


Figure 3.8: Overlay – Incremental impact of 2040s 2°C scenario on annual hydroelectric power production *(Exposure of Physical Assets to Climate Risks)*

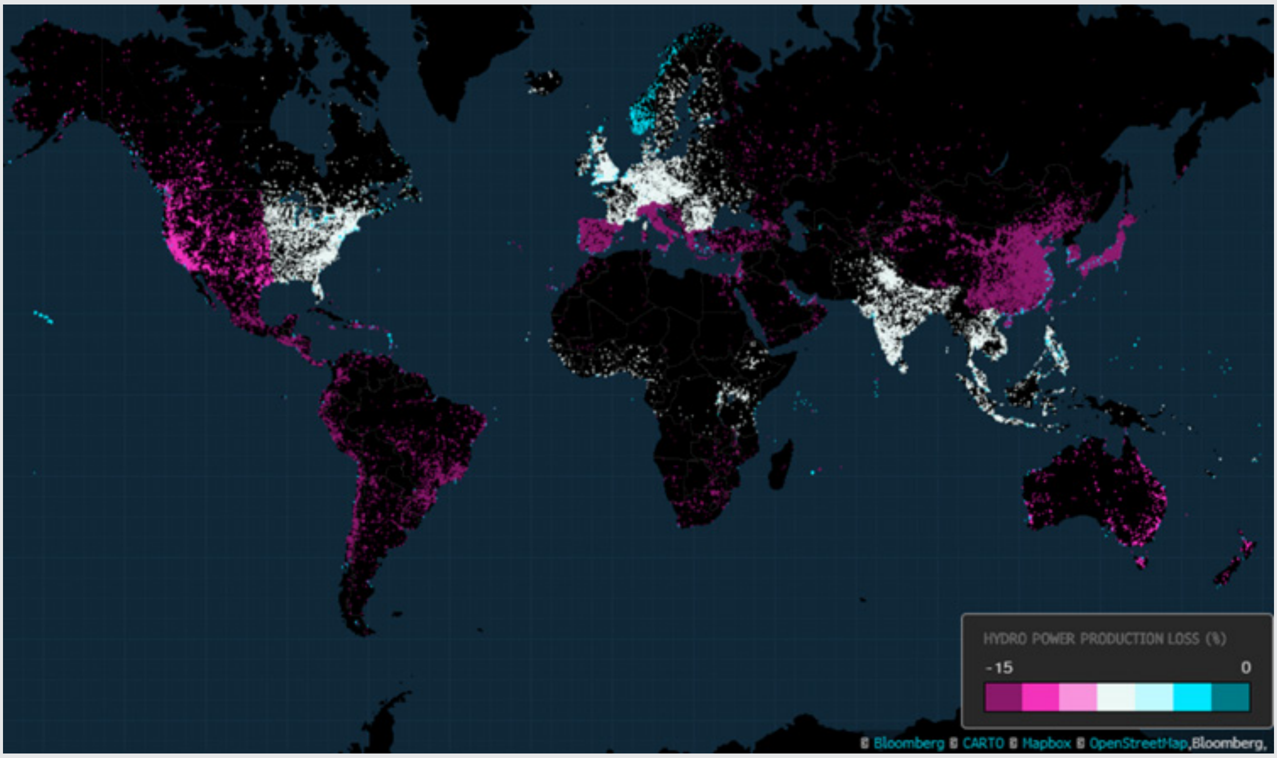
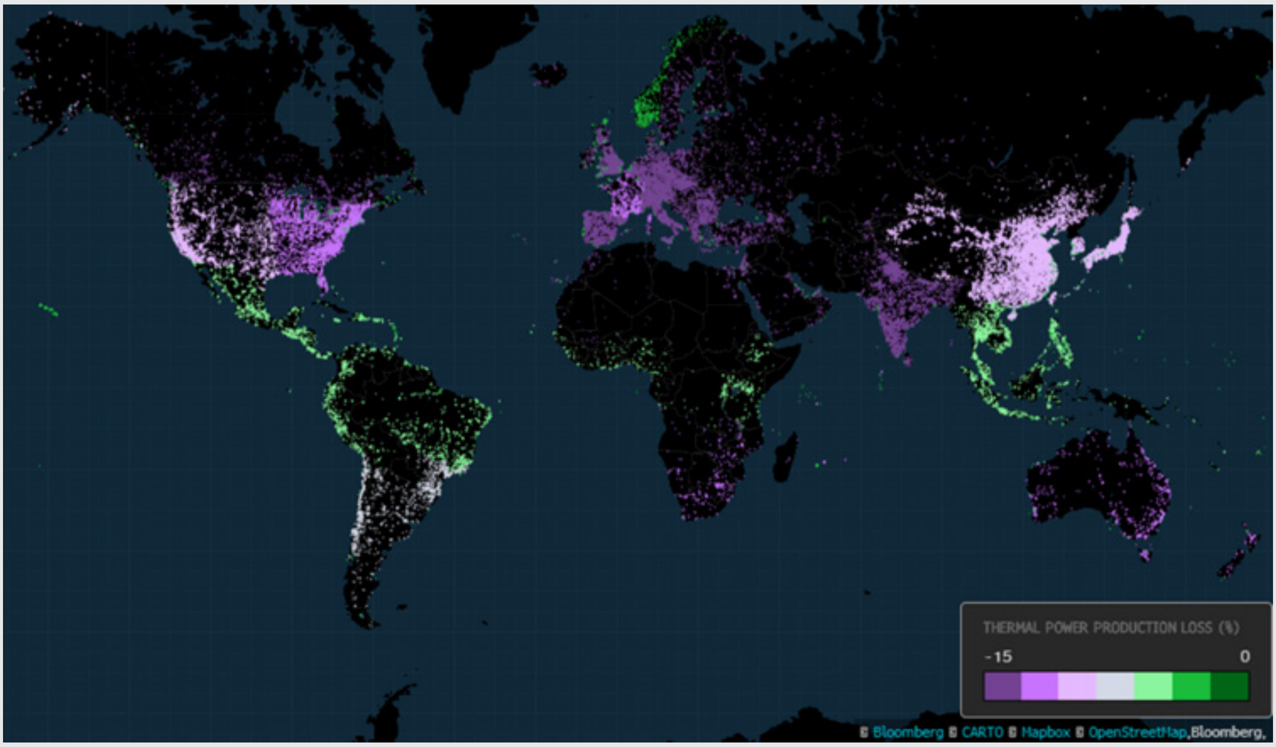


Figure 3.9: Overlay – Incremental impact of 2040s 4°C scenario on annual thermal power production *(Exposure of Physical Assets to Climate Risks)*



The geospatial analysis approach provides a simple and effective means of assessing physical risk. The Bloomberg MAPS tool is highly customizable and can draw on data from over 200 unique datasets. This functionality allows for the potential application of Bloomberg MAPS in the analysis of physical risk for other sectors using an approach similar to that described above.

3.3.3. Results

The assessment of the three climate scenarios yielded three main observations:

1. Under all scenarios tested, the majority of the borrowers in the sample experienced a one notch downgrade in credit rating (e.g., from AA to AA-), conservatively assuming that no capital expenditures were made to reduce production losses from incremental climate change and extreme events.
2. The 2040-4°C scenario saw the greatest number of borrowers experiencing downgrades in credit rating, which is expected given that this scenario depicts the most significant impacts on productivity of power utilities.
3. Decreases in borrower revenues are primarily driven by incremental climate change. The impact of extreme weather events on borrower revenue was found to be insignificant.

3.3.4. Conclusion

Benefits and insights: the geospatial approach to assessment of physical risk from climate change is flexible and scalable and can be applied to a range of sectors and climate scenarios, assuming data are available. The visual approach is also useful in quickly pinpointing areas for further study, and facilitating discussions with stakeholders.

Data: Some data inputs were not readily available. For example, some company data were not available via existing Bloomberg datasets and had to be extracted manually for each borrower. The alignment of bank credit models to the Acclimatise methodology required some simplifying assumptions and/or manual input.

Future enhancements: Further developments to the Acclimatise physical risk assessment methodology could improve the quality of analysis. Specifically, the addition of climate-related production impact information for facilities with other fuel types (e.g., nuclear, other renewables), alternatives to revenue and COGS as the financial link to climate impacts, and a deeper evaluation of the short-term impacts from extreme weather events as they are not significant relative to incremental change given the medium to long term nature of the scenarios tested.

3.4. UBS CASE STUDY: ASSESSING PHYSICAL CLIMATE RISK TO ELECTRIC UTILITIES COMPANIES

3.4.1. Approach

We performed a bottom-up sensitivity analysis for financial vulnerability to physical climate risk of borrowers within our electric utilities lending portfolio. The aim was to estimate the financial impact of physical climate risk on this portfolio, which required translating climate risk data into change in probability of default (PD). Our environmental and social risk, credit risk and rating methodology teams were involved in applying the methodology.

The regional scope of our analysis was the United States and Europe. We included individual assets (power plants) owned and operated by borrowers, including the assets in their subsidiaries.

We used Bloomberg MAPS geospatial analytical technology to identify the location of each asset and to understand the climate-related risk factors for each asset.

The methodology requires analysis of climate risks for each asset individually which presented practical/logistical limitations. The high number of climate risk data points per asset makes aggregation at the borrower level time consuming and on portfolio level less manageable (for example, approximately 1m data points to analyze for a portfolio of 20 borrowers for two scenarios, as suggested by the methodology).

For the purpose of this piloting exercise, we therefore decided to do a deep-dive into one borrower, whose assets are located primarily in the southern United States. The methodology found a 14.5% impact on production capacity from incremental climate change in a 2020s - 2°C & 4°C scenario, as compared with a present-day baseline. A further 0.24% impact on production capacity from extreme weather events is also found in a 2020s - 2°C & 4°C scenario, driven primarily by heat waves and river flooding, again compared with a present-day baseline.

The methodology then suggests to equivocate changes in production capacity into revenue change and to use this as a basis to analyze change in PD. This was challenged by some internal teams, for several reasons, including that holding all things equal did not allow consideration for broader market dynamics. For example, loss of production capacity from extreme weather events would only have a credit-relevant impact (by the 2020s) if one simultaneously assumes that there is no spare capacity, the price is fixed by regulators (or the market price will not spike up, as the remaining producers do not lose capacity for the same reason), there is no insurance, existing reserves are not sufficient to reinstate production capacity, there is no emergency funding from a local authority dedicated to preventing power outages and the service capacity of the existing debt will be permanently decreased to a level that leads to a downgrade.

3.4.2. Benefits and challenges

One of the major benefits of this project is how it shows the relevance and positive outcome of collaboration within the industry. It is a great achievement that Bloomberg has now incorporated physical climate risk data points into their MAPS application. They have also offered to collaborate in the future, to further improve the functionalities and to cater to the users' needs. The main gain is efficiency in applying this methodology as various risk data points are mapped to individual assets by the tool instead of in a manual way.

This project helped to even better understand the data and methodology challenges that lie ahead. As physical climate risk data are limited and assumptions had to be made along the way, questions are raised about their robustness and the need for improvement (e.g., downtime of utilities from extreme weather events based on public media search).

Another example is that the methodology necessitated simplification of the climate risk data, for usability, in order to compute the impact on production capacity. These simplifications reduce potentially relevant information, such as severity of an extreme weather event or regional differences in asset downtime, which arguably reduced the robustness of the key output variable.

The question of how to translate such climate risk data into financial impact on individual companies is not fully answered. The single methodology output variable does not provide enough information to form an appropriate credit view at the borrower or portfolio level. Translating change in production capacity into revenue changes, leaving everything equal, does not consider supply/demand dynamics in the electricity market.

3.4.3. Potential next steps / areas of future work

Electric utility companies aligning their climate-related risk disclosures with TCFD recommendations (and, therefore their own scenario analyses) would allow banks to use these disclosures in conducting a portfolio-wide analysis and reduce data challenges.

Concurrently, a more robust partnership going forward with the insurance industry could also improve the quality of data inputs (e.g. asset downtime estimations from extreme weather events, costs), while providing linkages to analytical tools (like spatial risk analysis platforms).

Further analysis should also examine systemic impacts within the market, sector, and wider economy, in order to accurately reflect true impacts to the credit worthiness of borrowers. A few examples include linkages of near-term capacity shortages to the electricity market (and pricing), new-build of (potentially more resilient) capacity, and a potential risk-mitigating policy response.

3.5. STANDARD CHARTERED CASE STUDY: COMMERCIAL REAL ESTATE IN CHINA

3.5.1. Background and scope of analysis

Standard Chartered chose to examine the impact of physical climate risks on property assets securing some of its corporate exposure portfolio. Our focus was on the impact that extreme events, including storms, floods and wildfires, may have on the portfolio of assets where the primary source of debt repayment is from real estate assets, i.e. our Commercial Real Estate (CRE) assets. We recognize that the effects of incremental climate change on property assets is much harder to quantify without exploring the design and use of individual property assets and thus their resilience to incremental climate change, such as changes in precipitation patterns. Doing so would introduce significant complexity. Similarly, we did not include in scope all exposures secured by property collateral (e.g. working capital loans to a manufacturing company which is secured by a factory / warehouse).

Our objective was to determine whether an increase in the frequency of such extreme events as a result of climate change might cause a meaningful impact on the value of property held as loan collateral, impacting the loan-to-value (LTV) ratio and therefore the minimum capital requirements at a portfolio level.

As a lender operating across Asia, Africa and the Middle East, we have significant residential mortgage exposures in Singapore, Hong Kong and South Korea and exposure to Commercial Real Estate across our footprint. We brought together a cross-functional team to support this project – central co-ordination was provided by our Public Affairs & Sustainability team, with input from specialists from Risk, including modelers and credit risk officers, and client-facing business teams with experience in real estate lending.

3.5.2. Approach adopted for analysis

Initially, we set about examining residential mortgage exposures in Singapore, using Swiss Re's CatNet® tool[s] to obtain data on extreme events by location. However, the data in CatNet® for Singapore was limited. We therefore decided to focus on another geography, to obtain a more meaningful distribution of climate-related risks. We judged that we would experience similar challenges in our other main mortgage markets, so we focused on Commercial Real Estate exposures in China. We used our central credit database to identify all real estate assets located in mainland China and uploaded an anonymized version of this data to CatNet®.

For the purposes of this exercise, our focus was on the real estate exposures to Income Producing Real Estate (IPRE) or CRE exposures. Further work may be needed to consider circumstances where real estate collateral forms only one part of the package of security pledged to a bank in return for a loan. Since the focus of the property assessment tool was the value of property assets, we did not derive any estimates of changes to borrower revenues, or consider broader impact of incremental climate change on the suitability of real estate assets for their intended purpose, (e.g. whether there will need to be further capital investment in properties to address rising temperatures).

s. www.swissre.com/clients/client_tools/about_catnet.html

3.5.3. Results and impact assessment

Our analysis demonstrated potential valuation impacts that could arise from the anticipated physical climate impacts assessed during this exercise. These valuation impacts could require reconsideration of some of the criteria (e.g. collateral value, LTV) feeding into our capital calculation models. For the purposes of this exercise, we assumed all physical impacts occurred at their shortest return period, but note that in reality this is unlikely to occur.

Some regulatory capital approaches to IPRE operate on a 'slotting' basis, with a limited number of 'slots' or groups into which loan exposures are allocated based on a number of factors. In such situations, re-allocation of exposures from one slot to a lower-rated one can have significant impact on the level of capital which has to be held against the exposure. This can exacerbate the impact of otherwise small movements to factors such as the exposure's LTV. However, it should be noted that our CRE portfolio is prudently managed following strict underwriting guidelines as demonstrated by the low average LTV, with a significant majority having lower than 50% LTV and short remaining tenor, consistent with the 3 year tenor assumption used by banks in this pilot exercise.

Around two thirds of property locations showed some increased physical risks as a result of climate change projections. However, many of these had no appreciable impact on the LTV ratio of loans secured against the properties – only around a quarter experienced a deterioration of above 1% in LTV and therefore considered 'at risk', with the most significant impact being a 5% deterioration in LTV. The Risk-weighted asset (RWA) impact at a portfolio level therefore was immaterial.

It is noted that the wildfire data, which draws upon a short historical record (11 years) to infer current frequency, seemed to over-estimate the likelihood of impact and there was strong correlation between those properties at risk of wildfire, and deterioration in LTV in this exercise. Further desktop review of the individual properties with elevated wildfire risk may help to determine whether this is a viable risk.

In contrast, flood data were not available for China via the CatNet® system. We therefore turned to the flood return datasets provided in the UNEP GRID Global Risk Data Platform[t] to identify property-level flood risk return periods as an alternate, publicly-available system. This proved difficult and seemed to indicate infrequent return periods and in many cases no flood risk. It is considered that this risk may be under-estimated and needs further review to identify other data sources.

t. preview.grid.unep.ch/index.php?preview=map&lang=eng

3.5.4. Areas of further work identified

Data availability and manual processing

In using CatNet® to assess our Chinese CRE portfolio, we found meaningful data on storm and wildfire hazards. However, we found the system did not provide data on flood. For this risk, we used UNEP GRID Global Risk Data Platform and also the global flood protection standard (FLOPROS) database.[u] We were able to obtain information on flood risk, but note that this required significantly more manual intervention than data processing using CatNet®. In total, the level of manual processing required to gather and format data from internal systems into one usable in external platforms, pass data through these platforms and aggregate the results was substantial and is something that should be considered when seeking to scale-up the forms of analysis undertaken in this pilot.

Data quality and validation

Other challenges and areas for improvement are the quality and accuracy of the actual data points themselves, in terms of heightened risk of wildfire or flood. For instance, certain locations were not completely aligned to intuition (e.g. different risk levels between properties which are in close proximity, heightened wildfire risks in some properties within a city surrounded by two rivers with the nearest forest-like area being 25km away).

3.5.5. Conclusion

Undertaking the analysis has helped us in multiple dimensions. Most immediately, it enabled us to bring a team of individuals together from across the Bank to look at a facet of climate change risk, and in doing so allowed us to continue to build knowledge and capacity in this area. More generally, it has allowed us to understand the potential scale of physical climate change impacts on the CRE portfolio and thus inform our assessment and management of such risks, and development of internal capabilities to respond to these.

The methodology used for this project necessarily made a number of assumptions – most critically the potential value impact on property collateral from any climate-driven extreme event (flooding, storm or wildfire), which we hope can be tested and refined over time. If the types of tool we used in this exercise are to be taken up more widely across banks' portfolios, and by a greater number of banks, 'one stop' analytical sources will be required that avoid the need for manual processing of information through multiple databases – or in the case of UNEP GRID Global Risk Data Platform, manual look-up of individual properties.

u. www.nat-hazards-earth-syst-sci.net/16/1049/2016/

Rabobank

3.6. RABOBANK CASE STUDY: GETTING PHYSICAL WITH DUTCH REAL ESTATE

3.6.1. Scope

We have focused the analysis of this pilot on the retail real estate sector's susceptibility to flood risk in the Netherlands. The reason for this is threefold. Firstly, Rabobank is one of the largest retail mortgage providers in the country and retail mortgages also represent a significant share of its total loan portfolio. Secondly, the Netherlands is a country that is well-known to be highly susceptible to flood risk, due to sea level rise and river flooding. According to the PBL Netherlands Environmental Assessment Agency, 26% of the Dutch territory is below sea level and 29% is susceptible to river flooding. Moreover, 70% of the economic activity and 52% of the population is based in high-risk areas.[v] Finally, the physical risk methodology also covers wildfire and cyclonic risk, however data available on cyclone risk in 100 years indicates that the Netherlands is not susceptible to this type of extreme event. There are no data available on wildfire risk but the absence of widespread forest areas in the Netherlands makes it plausible that such a risk is negligible.

3.6.2. Challenges and workarounds

Internal data

The main challenge with internal data was to obtain a high level of granularity. As retail mortgages are related to natural persons, very strict privacy rules apply to this portfolio's data. Consequently, access to debtor-level data is restricted. Access might be granted through special permissions from compliance but, given the tight timeframe of this pilot, we decided to work around this limitation and use readily-accessible data. For this pilot, we worked with exposure data aggregated at the level of four-digit zip codes, which anonymized the data. The method developed by Acclimatise also required us to make assumptions regarding the value of the underlying property and the portfolio's average age to maturity. We assumed the value of the underlying property was equal to the exposure. We find this plausible given the fact that Dutch mortgages are typically characterized by a high loan-to-value and the lion's share is free of repayment (according to a report from the Dutch Central Bank in 17Q2, only around 20% of mortgages have a linear or annuity payment). Our assumption on the average age to maturity is based on the average age of the mortgage portfolio and a maximum tenor of 30 years. The number is also confirmed by Dutch Central Bank data on the estimated peak of mortgage debt in the Netherlands.

External data

The main challenges with external data was linking the data to our internal data. Most available databases (e.g. Bloomberg MAPS, World Resources Institute Aqueduct) do not report flood risk at the zip code level. These datasets also do not have any common fields that could be directly linked to zip codes. Databases that actually provide such location-specific information (e.g. Swiss Re CatNet®) are often difficult to use for an extensive portfolio. These databases only allow the upload of a limited number of (client) addresses and subsequent download of connected climate change data. To cover the whole credit portfolio this process would need to be run many times over, which would be a huge operational burden. Additionally, an initial test resulted in many unknown addresses in CatNet®.

v. Source: www.pbl.nl/dossiers/klimaatverandering/content/correctie-formulering-over-overstromomgsrisico

The Dutch government provides detailed analyses of flood risk. While flood risks surpass provincial/zip code borders, for instance, these risks could in fact be translated to risks per zip code, as zip code areas are sufficiently small. Moreover, this national dataset goes further than other globally available datasets by additionally providing flood estimates for the 1 in 1000 year return period.[w] The dataset also provides information on the severity of flooding per zip code. However, we have not included this information in this pilot for consistency purposes. The use of national data is in line with overall recommendations in the physical risk methodology.

3.6.3. Analysis and outcome

Based on the data and assumptions above, we used a flood return period of 1 in 1000 years (Figure 3.10) and an average age to maturity of 20 years. In line with research undertaken by Acclimatise, we applied a +25% change in future flood frequency for the Netherlands, which resulted in an encounter probability of 2.5%. Also applying the 10% (medium) estimated change in property value due to extreme events, we found an estimated exposure loss value of 0.13%. To stress the results, we also considered the worst-case scenario for the Netherlands: a change in future flood frequency of +35% and an estimated property loss value of 20%. That increased the loss up to 0.3%. A first look at the Dutch area at risk of flooding indicates potentially significant losses arising from flood risk. However, the calculated estimate losses of 0.3% of the mortgage portfolio value, in the worst case, suggests a limited impact on the portfolio as a whole.

Figure 3.10: Properties at risk of flooding in the Netherlands – 1: 1000 year return period

Source: Rijkswaterstaat, Rabobank

Part of the narrative behind the low impact is the high level of protection offered by the Dutch delta works and planned future upgrades. Highly sophisticated water management planning, coupled with a high degree of flood protection, mitigates flood risk across a large portion of the country. Indeed, while 59% of the Dutch territory is at risk of flooding, only 4% is not covered by the Dutch flood protection system. Moreover, the Government has

w. This is the flood protection standard in the Netherlands (1:1000 years).

planned to spend an additional EUR 7 billion up to 2028 in water safety infrastructure. That is particularly visible in data on flood risk in 2020 versus the same risk in 2050 (see Figure 3.11 and Figure 3.12). According to such information, flood risk will be reduced considerably between 2020 and 2050.

Figure 3.11: Flood risk in 2020

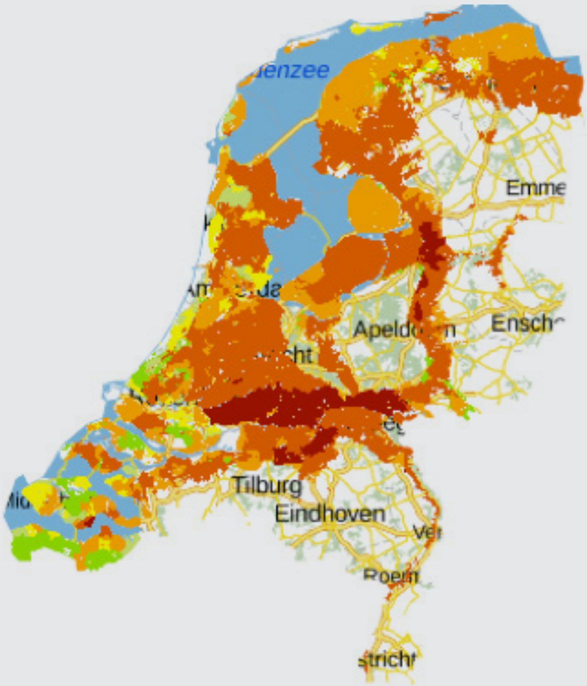
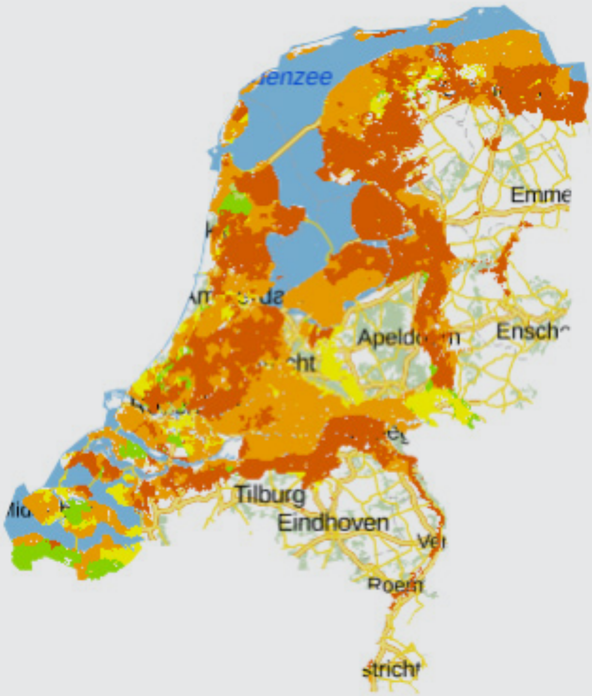


Figure 3.12: Flood risk in 2050



- Less than once per 1,000,000 years
- Between once per 100,000 and 1,000,000 years
- Between once per 10,000 and 100,000 years
- Between once per 1,000 and 10,000 years
- Between once per 100 and 1,000 years
- More than once per 100 years

Source: www.klimaateffectatlas.nl/nl/

To stress-test this sensitivity, we also calculated property value losses with a higher flood frequency, namely the 1 in 100 year return period. This led to a 10-fold increase in the impact on property value at 1.2% of the portfolio value. However, we note that the territory at risk of flooding from 1 in 100 year event (dark red surface in Figure 3.11) is only a small fraction of the area at risk from the 1 in 1000 year event. Hence, we note that this outcome is a significant overestimation of the actual property at risk given the current state of the Dutch flood protection infrastructure. As a compromise, we also ran the analysis using a 1 in 500 year return period, while keeping the area the same as at 1 in 1000 year event. This still resulted in a loss on the total mortgage portfolio of less than 0.3%.

3.6.4. Key takeaways and challenges

Overall we have found this pilot to be an important step forward in starting to think about climate change risk assessments. These first attempts also highlight that there is still a lot of work that needs to be done.

The methodology outlined in these pages constitutes a very valuable point of departure in our journey towards estimating the financial impacts from physical climate change. In deploying the methodology we have amassed numerous learnings while also having encountered various challenges.

One of the challenges we highlight is the fact that the frequency of events plays an important role within this specific methodology, while the occurrence of extreme events is likely to be significantly altered by climate change. Thus, the ultimate outcome is a very rough estimate. We also acknowledge that it will be necessary to undertake a continuous calibration that applies the latest insights with regard to climate change.

Another issue is the applicability of the outcome of this case. The way the measurement of climate change related risks was undertaken means that there are some limitations with regard to its utility for steering our strategy. Because we work with averages based on top-down information, the outcomes are therefore very rough estimates of the overall outcome. Only an assessment based on specific bottom-up information for individual debtors would allow the differentiation of winners from losers, which can help in steering overall credit/ risk strategy. In addition to this observation there is also the question on how to effectively communicate on the uncertainty of such rough estimates as to convey the message without too much undue "noise".

In more general terms working on the case studies for this project also identified various challenges that need to be addressed going forward on the TCFD path. One key challenge is that of data availability, this applies both to internal customer data as well as data used from external sources.

When it comes to climate change risk assessments we found that there is clear low-hanging fruit in the energy sector and in listed companies, because the information needed for the assessment (e.g. location of the assets or production facilities) is more readily available, e.g. from external data providers. The situation gets more complicated when assessing the impact in other sectors or for small to medium-sized enterprises (SMEs).

With regard to this point we found that there is a clear need to develop the internal bank infrastructure for recording climate-related information that would enable a bottom-up assessment. Using a methodology that is consistent and recognized within the sector and across sectors is very important for comparison and aggregation purposes. This way, the bank can gather data that fills existing gaps. Given the innovative character of such data collection, an important stepping stone is educating corporate clients on how to assess climate change risks and opportunities themselves, as well as on how to report these estimations consistently.

Internal cooperation within the bank also proved challenging and requires a significant effort. We found that most banks in this regard were facing similar challenges, e.g. getting everyone aligned internally on how to look at climate change risks.

Lastly, we also found that there is need to emphasize that climate change is not just about risks, but also about opportunities. With the proper tools in place it can help banks steer strategy and price in risk appropriately. This underlines the imperative of taking action sooner rather than later. And for this it is certainly worth remembering that the sooner they start, the sooner they can act.

3.6.5. Other observations

During our review of the various other sectors included in the pilot project such as commercial real estate and agriculture, we came across various challenges in applying the methodology as described in this report. One of the hurdles that need to be overcome is the size of the geographical area covered by zip codes. For instance, in the US and Australia, one zip code can cover a disproportionate amount of land, while climate change effects do not necessarily follow these borders.

In the case of commercial real estate, we encountered attribution issues that arose when there were multiple borrowers involved in the same project. A possible way forward is to look at the underlying collateral agreements. Other issues are related to the fact that there may be a separation of the data on the borrower on the one hand, and collateral on the other hand. Merely linking these different datasets together doesn't necessarily overcome the fact that the financed object is located in one zip code while the borrower is located in a different one. This issue is exacerbated when the borrower (as is often the case) has multiple objects located in different regions - thus generating income in different locations - with possible divergence in the impacts of climate change. This creates a challenge in isolating and identifying climate change effects.

4. PHYSICAL OPPORTUNITIES: EXPLORING AN INSTITUTIONAL STRATEGY

This Chapter provides a framework for assessing the strategic opportunities for banks to support actions that clients may take in response to physical climate impacts. The framework can be further developed and modified by banks using their own market and borrower-level data, as well as other socio-economic data, to develop more sophisticated scenarios. It should be considered as a starting point for the development of more detailed analyses.

In this project, 'opportunities' have been defined as the potential increase in demand for commercial and retail finance and wider banking support and advisory services driven by the physical impacts of a changing climate. The TCFD[22] describes "climate-related opportunity" as "the potential positive impacts related to climate change on an organization". This should not be taken to imply that climate change can be a positive process and nothing in this Chapter should be taken as implying that it is beneficial. The framework provides a strategic market analysis within the context of a bank's institutional capacity and market positioning to identify the most relevant opportunities. It will show where a bank is best placed to assist their customers in supporting adaptation and resilience actions.

The framework sets out a taxonomy of opportunities relevant to banks based on managing existing risks, responding to emerging risks and preparing for market shifts. This can assist banks in understanding the potential finance needs of their clients, and the role of banks in providing finance for climate resilience. This is not an area which has been extensively researched and there are very few published examples which speak directly to the interests of the financial services sector. The framework's activities and tasks are shown in Table 4.1.

Opportunities will depend on each banks' specific strategies and business models. A generic, top-down analysis of opportunities is unlikely to capture the specific portfolio profiles of each bank nor capture the scale and value of these opportunities. This framework is designed to assist banks in identifying those opportunities, which should be evaluated consistent with banks' internal strategies and procedures. Analysis of the opportunities should incorporate the views of industry sector experts within a bank and reflect its capacity to respond to changes in market conditions.

Not all opportunities will be immediately relevant to a bank and its business model, because of the time horizons over which they will occur. The framework explores this and assists banks in identifying those opportunities which should be evaluated and disclosed consistent with both their credit risk models and the expectations of their customers and their investors.

Market analysis data for banks, exploring the demand and timescale for capital driven by the impacts of a changing climate on borrowers, are not readily available. Some indication of potential demand can be deduced or implied by reference to publications produced by international development banks and development partners, or by governments in sectoral climate vulnerability and risk assessments (CVRAs) and National Adaptation Plans (NAPs). In this project, the framework explores how such publications can be used to assess opportunities, although the limitations will require banks to rely on additional judgements and assumptions.

Capital requirements to meet the challenges of a changing climate will vary across sectors and geographies, and will be influenced by global, regional and national market conditions, and by policy and regulatory drivers. The framework recognizes the variations and uncertainties in these factors, and the need for banks to assess future impacts on their business by sectors and markets, rather than at an aggregated, business or economy-wide level.

The framework recognizes that the process of disclosure of opportunities arising from the impacts of a changing climate is embryonic, and that the release of forward looking statements can be challenging. There are no agreed methodologies for assessing and disclosing opportunities arising from, and in response to, the physical impacts of a changing climate. It is premature to expect to see quantitative analyses being directly incorporated within regulated financial reports. Qualitative 'soft' reporting is currently more easily achievable, and this may be the method many corporates choose to adopt in the near term to facilitate assessment by shareholders.

Table 4.1: Opportunities framework activities and tasks

OPPORTUNITY ASSESSMENT FRAMEWORK			
	Activity	**Task**	**Objective**
1	Taxonomy of opportunities	Define opportunity categories	Agree how opportunities can be defined
2	Market analysis	A. Sector finance demand	Estimate the future finance demand by sector and country arising from a changing climate
		B. Sector assessment	Identify the sectors with the most significant lending and advisory service opportunities at a granularity relevant for decision-making
3	Bank institutional capacity and positioning	Scorecard for each sector and country	Assess the capacity and positioning of the bank to take advantage of opportunities in view of the impacts on markets over time, and the potential for market shifts as sectors respond to significant changes in their value chains
4	Opportunity evaluation	Combining the market analysis with the bank's assessment of their institutional capacity and positioning	Identify the sectors with the highest potential opportunities

4.1. TAXONOMY OF OPPORTUNITIES AND DATA SOURCES

Opportunities in lending, banking support and advisory services are being created by a changing risk landscape driven by the impacts of climate change and the responses to those impacts by corporate and retail borrowers. The framework includes a generic taxonomy of opportunities recognizing that there is a temporal dimension to be considered. As the acute and chronic impacts of a changing climate become more pronounced, the risks and opportunities landscape will also evolve, requiring different levels of response (and investment). The effects of a changing climate on social, economic and environmental systems at macro- and micro-scales are already evident. Finance and banking support are required by customers to manage existing risks, respond to those risks that are beginning to emerge, and to prepare for significant changes in markets.

Table 4.2 sets out a taxonomy of potential opportunities together with the timescale in which they will be relevant. The timescales provided are indicative and can vary according to sector.

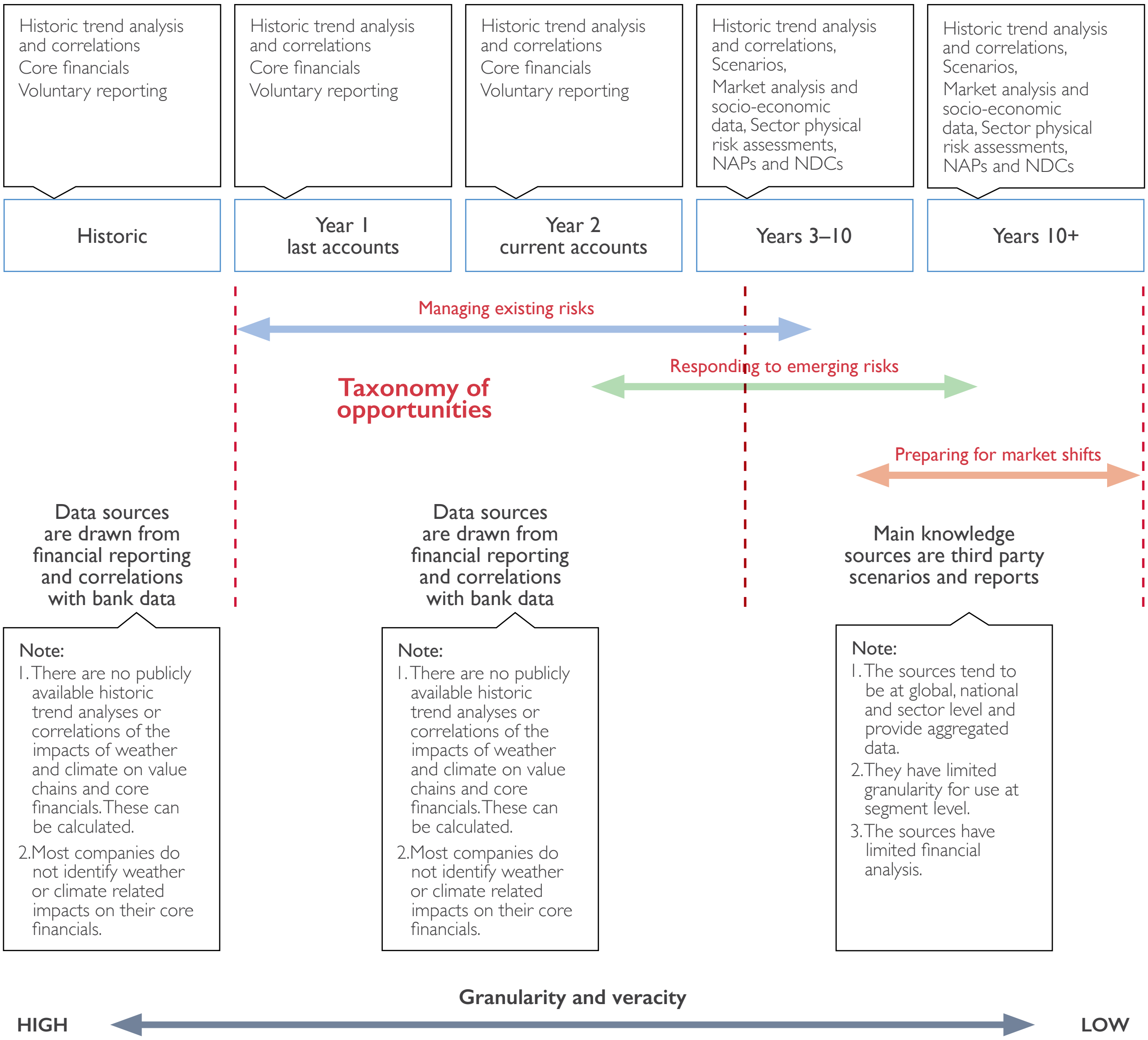
Table 4.2: Opportunities taxonomy

CATEGORY	DESCRIPTION	ROLLING TIMESCALES
Managing existing risks	Commercial borrowers manage existing climate risks that are affecting revenues and costs. For example: extreme event preparation, contingency planning, event recovery, changes in operating performance of assets, cash flow financing.	1 to 5 years
Responding to emerging risks	The changing risk landscape and the adverse or beneficial impacts on value chains will create additional demands for finance and advisory services.	2 to 10 years
Preparing for market shifts	The fundamental shifts in climate over the longer term will have impacts on value chains with changes in revenues, costs and expenditure. For example, in the retail mortgage sector there is likely to be an increased demand for loans for home improvements to cool houses, in agriculture chronic changes in precipitation and temperature may result in farmers changing their business models and moving into alternative crops.	8 years and beyond

The data and knowledge sources relevant to the three categories of opportunities and their timescales are provided in Figure 4.1. The main potential sources are:

- **Company financial data**. This should be the main source of data in understanding the opportunities arising from managing existing risks, however there is a challenge in that companies are not identifying the impacts of climate change or the expenditure on adaptation measures and resilience building in their core financials and accounts. Annual accounts present aggregated data; climate impacts on core financials, including expenditure on adaptation responses and building resilience, are not separately itemized. Corporate data should be an excellent source of auditable information but at present accounting practices are inconsistent with the assessment and disclosure of opportunities.
- **Voluntary corporate reporting**. Sources such as the Carbon Disclosure Project (CDP) can provide alternative data, although these are dependent on the questions asked and the validity of the responses. CDP have aligned their questions with the TCFD recommendations. The reporting is undertaken by corporates and does not specifically cover micro, small and medium enterprises (MSMEs).
- **Analyses of the impacts of weather and climate on value chains and core financials in recent years**. This would provide signals and correlations to use as indicators of changes in risk and opportunity, and act as a baseline for further analyses using the outputs from climate and sector impact models. There are no published correlations available for use, but it would be possible for banks to undertake this exercise working with their clients.
- **Outputs from the sector physical risk assessments.** Using the methodologies set out in this report will provide indications of the level of demand for finance.
- **Third party scenarios and reports**. There is a plethora of published reports at country and sector and topic levels, including NAPs, Nationally Determined Contributions (NDCs) and sector CVRAs. These can be used to secure expert views on opportunities arising from existing and emerging risks, market shifts and overall investment needs. However, these reports provide limited information on the scale of finance to be provided by banks to meet the levels of investment identified.
- **Market analyses**. There are a limited number of examples of published market analyses identifying finance needs for specific sectors in a country driven by physical risks of climate change.[23] These have been produced by international development banks and can provide a template for banks to undertake their own analyses.

Figure 4.1: Opportunities framework data sources



4.2. ASSESSING THE MARKET

The process for undertaking market analysis contains two elements: sector finance demand and sector assessments.

4.2.1. Sector finance demand assessment

Not all resilience and adaptation measures will require finance. It will be possible for the banks' commercial customers to respond to some climate impacts by changing operational practices, accepting risk etc., with no additional operational expenditure (OpEx) and capital expenditure (CapEx) requirements. Investment needs may also be secured from other sources than debt financing.

The scale, timing and format of investment demand when considering market shifts over a longer period will be determined by multiple macro social, environmental and economic drivers in addition to those arising from a changing climate. This will increase the level of uncertainty and difficulty in providing quantitative assessments. The opportunities framework, which is focused on the impacts of changes in climate, can be further refined by developing comprehensive scenarios to consider the interplay of multiple drivers and their impacts on investment and finance demands. Using data held by banks may provide additional insights to refine the framework by assessing borrower preferences on sources of investment, including debt finance.

The first step in the market assessment is to examine published global, country and sector reports and scenarios of the costs of adaptation, to provide broad indications of overall investment needs. However, the focus in research on adaptation and resilience has been on assessing the impacts and only more recently on understanding the costs. It should also be noted that the available research provides limited analysis of the difference between OpEx and CapEx, the finance opportunities for banks, and the relative proportion of investment to be funded by public and/or private sources.

There are a limited number of published scenarios which provide estimates of the scale of the investment needed to adapt and build resilience to a changing climate. However, they focus on overall investment needs in developing countries and do not provide information on finance requirements. Their use should be treated with caution as there is often a relatively low confidence in their results due to methodological challenges, generalized assumptions and data shortcomings.

Historical borrower-level data can be an invaluable tool for assessing finance needs. A bottom-up, highly granular approach using company data (including analyses of the impacts of weather and climate on value chains, core financials and loan portfolios in recent years) would provide signals and correlations to use as indicators of changes in risk and opportunity in the immediate and near term – up to 10 years. These can also act as a baseline for further analysis using the outputs from climate and sector impact models. Banks are recommended to explore this approach.

4.2.2. Sector assessment

Further analysis is required to enable banks to identify the sectors with the most significant lending opportunities at a granularity relevant for decision-making.

Three steps are proposed:

- By referral to the outputs from the sector physical risk assessments undertaken as part of the UNEP FI TCFD project:
- Developing sector market analyses; and
- Using a scorecard to assess the attractiveness of sectors within each target geography and opportunity category/timescale, and to develop the level of granularity needed.

The analyses carried out as part of the physical risk assessments provide information on the impacts on yields, revenues and incomes. These impacts can provide indicators of potential finance needs, for example, cash flow financing if farm incomes become subject to greater seasonal variation due to changes in precipitation and drought.

Developing market analyses for specific sectors using examples developed by international development banks is recommended. They can be used to further develop relationships with borrowers, help them understand their risks, and identify technological and finance needs and opportunities caused by a changing climate.

A scorecard has been developed to assess the attractiveness of sectors within each target geography and opportunity category/timescale. The scorecard (Table 4.3) provides a qualitative assessment of each sector's potential reaction to key drivers. This allows banks to prioritize which sectors and countries they should focus on for more detailed analysis. The scorecard provides guiding questions and indicator sources against three drivers: policy and regulation impact; technology evolution and relative performance; and value chain impacts on core financials. Banks can use the scorecard as a template and introduce their own drivers and guiding questions and link this to their own credit risk models.

Table 4.3: Scorecard for assessing potential finance drivers

DRIVER	ASSESSMENT CRITERIA	GUIDING QUESTIONS	INDICATORS	SCORING		
				Existing risk	Emerging risk	Market shifts
Policy and regulation impact	Will changes in policies and regulation have an impact on the sector's market	Is this sector likely to be a target of specific regulations e.g. changes in operating standards?	▪ NAPs and NDCs ▪ Sector policy statements			
		Is the sector likely to receive grants or subsidies?	▪ Sector policy statements ▪ Previous state action			
		Does the sector export to, or import from other countries where policies and regulations may have an impact?	▪ Import and export data ▪ NAPs and NDCs in import and export countries ▪ Sector policy statements in other countries			
Technology evolution and relative performance	Will the sector's products and/or services provide competitive solutions to adaptation and resilience challenges?	Does the sector produce products or services which can replace competitors' products?	▪ Market and product service analysis			
		Is the product or service market likely to become fragmented or consolidated?	▪ Market concentration			
		Is this sector competitive with other sectors providing alternative products and services?	▪ Market technology scan			
Value chain impacts on core financials	How will the sector's core financials be impacted by adaptation and resilience responses in its value chain?	Is the supply chain likely to become more expensive resulting in increasing costs?	▪ Commodity prices ▪ Core financials ▪ Sector CVRAs ▪ Market analysis			
		Are operational and production processes likely to be impacted, requiring new investment?	▪ Sector CVRAs ▪ Core financials ▪ Market analysis			
		Is the sector likely to experience increasing variability and/or changes in demand?	▪ Sector CVRAs ▪ Core financials ▪ Market analysis			

HIGH (5–6) - High impact
MEDIUM (3–4) - Moderate impact
LOW (1–2) - Low impact

BOX 4.1: Bank case study on opportunities to assist companies making adaptation investments

One bank in the Working Group has noted potential opportunities to assist customers with climate change adaptation investments (as well as transition-related investments). This capital expenditure is central to the mainstream activities of customers as they seek to manage and adapt to climate change. Two examples are provided below.

Example 1: New power plant

A new power plant being built requires allowances for additional planning and costs to defend against storm and sea surge. As part of the project's feasibility study, hydrodynamics modeling of sea level was performed to factor in wave height changes over a 50 year return period. Based on the results of the feasibility study, the design grade level of the site was established to be at least +3.5m above Mean Sea Level (MSL), which is about a 2-3m increase from the current elevation. Drainage systems are also required to keep the site out from impounding water and as a flood mitigation. This requires ~ 30,000 cubic meters of fill needing up to ~1000 days to allow time for the fill to settle for building upon. This kind of investment disruption requires innovative financial sector engagement to assist in managing higher and more volatile costs.

Example 2: Rail network company

A rail network company linking more than 40 mines and three major ports is rolling out remote weather and track monitoring stations to provide real-time data on weather and track conditions. The company has also invested with government agencies to develop support tools to assess the risk and impacts of climate change across mining supply chains. This has resulted in initiatives to:

- Improve position of inventory stockpiles with additional ballast, rock, rail and formation material;
- Engage with customers on the estimated recovery timelines from disrupted services and work with customers to manage disruption from weather events;
- Establish protocols for the recovery of stranded rolling-stock;
- Embed spatial imaging tools and drone photography for events that involve large-scale earth works;
- Rebuild slopes with lower gradients where forecast to be affected by major land slips, and reinforcing with high strength rock and concrete; and
- Expand drainage capacity by replacing pipes with concrete culverts, and reinforcing embankments.

It is incumbent on the financial system to work with government, industry and customers to understand the financial impact and help manage the financial cost and disruption associated with long-lived investments and impacts of climate change.

4.3. ASSESSING A BANK'S INSTITUTIONAL CAPACITY AND MARKET POSITIONING

In view of the changing climate impacts on markets over time, and the potential for market shifts as sectors respond to significant changes in their value chains, the institutional capacity and positioning of banks should be assessed.

A scorecard has been developed to assist in the evaluation of a bank's capacity and market positioning. The scorecard (shown in Table 4.4) provides guiding questions and indicator sources against three drivers: competitive landscape, risk appetite and institutional capacity. Banks can use this as a template and introduce their own drivers and guiding questions, as necessary.

Table 4.4: Scorecard for assessing a bank's institutional capacity and market positioning

DRIVER	ASSESSMENT CRITERIA	GUIDING QUESTIONS	INDICATORS	SCORING		
				Existing risk	Emerging risk	Market shifts
Competitive landscape	How is the bank positioned in each sector when compared with its competitors?	Is there an opportunity for the bank to increase its market share over time? What is the current and planned market share?	▪ Comparison of bank market share with those of competitors ▪ Market research			
		Are there barriers to market entry and/or scale?				
HIGH (5–6) - Bank is competitively positioned to be a market leader MEDIUM (3–4) - Bank is positioned to compete with others LOW (1–2) - Bank faces significant challenges to compete						
Risk appetite	How is the bank's risk appetite aligned with the sector risk profile?	How is the physical risk landscape expected to change e.g. changes in sector probability of default?	▪ Historical performance of the sector ▪ Physical risk analysis			
		How does the bank's risk profile for the sector compare with the sector's future profile?	▪ Bank's sector risk profile			
HIGH (5–6) - Sector is strongly aligned with bank's strategy MEDIUM (3–4) - Sector is loosely aligned with bank's strategy LOW (1–2) - Sector is misaligned with bank's strategy						
Institutional capacity	How is the bank positioned to capture the sector opportunity?	Does the bank have specific sector expertise?	▪ Analysis of bank's institutional capabilities, expertise, data, financial capacity			
		Does it have a sufficient sector database to assess and price the opportunities?				
		Can the bank extend capital to the sector?				
		Is the bank active in investment ecosystems adjacent to the sector?				
HIGH (5–6) - Bank has a high level of institutional responsiveness MEDIUM (3–4) - Bank has an adequate level of responsiveness but will require additional resources LOW (1–2) - Bank does not have the required level of responsiveness and is unlikely to acquire the additional resources						

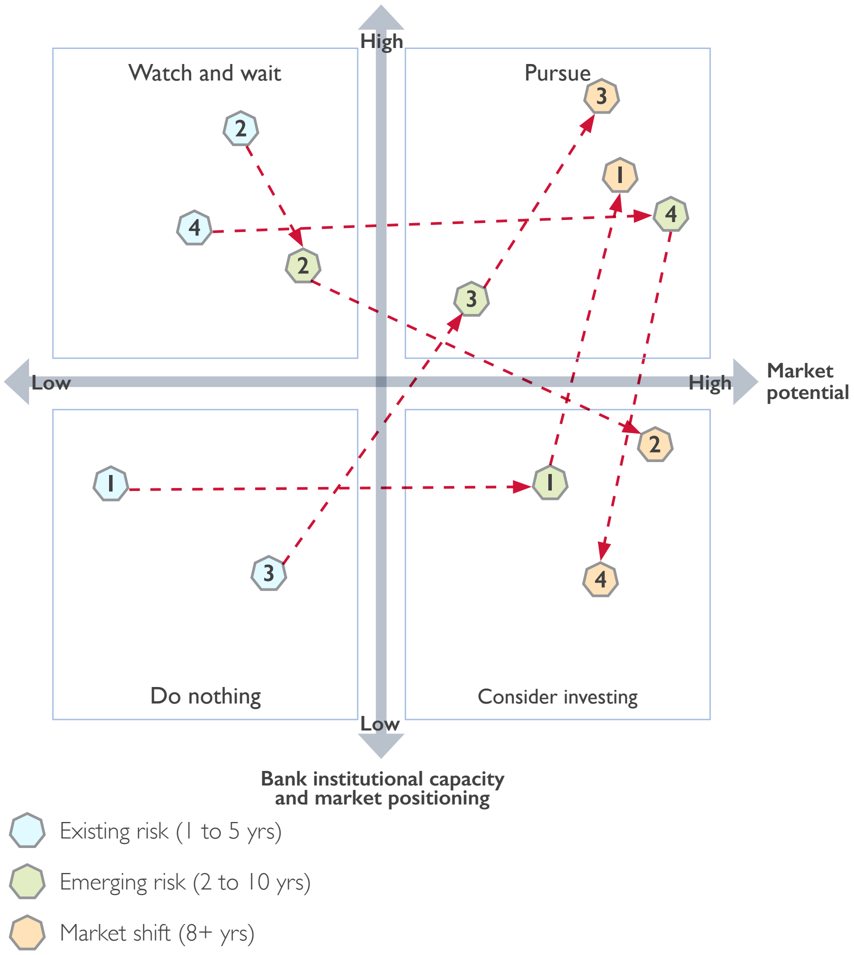
4.4. EVALUATING OPPORTUNITIES

The results from the combined scorecards can guide banks on their potential lending strategies. They provide a structure to enable banks to consider the implications of a changing climate and how it can:

- Increase lending to those sectors requiring finance to take advantage of increased demands for their products/services;
- Support those sectors requiring finance to adapt and build resilience; and
- Consider actions to guide and advise clients on managing their business and responding to climate change through client relationship processes (thereby protecting/improving credit risk ratings).

By combining the scorecards produced from the market assessment (Table 4.3) and the evaluation of a bank's capacity and positioning (Table 4.4), an understanding of sector opportunities can be developed relative to the timescales and taxonomy of opportunities. Figure 4.2 illustrates a useful way to consider shifts in institutional capacity and market positioning over time. For sectors and opportunity categories falling within the top right quadrant, banks may choose to pursue this market opportunity and increase investment in their capacity and positioning. For sectors and opportunity categories in the bottom right quadrant with good market potential, banks may consider the need for internal investment to take advantage of the opportunities. Where a bank has a high level of capacity and positioning, but the market indicates low potential (top left quadrant), watching and waiting to see how the market evolves may be appropriate. Where a bank's capacity and positioning and the market assessment are low (bottom left quadrant), choosing the 'do-nothing' option may be more appropriate.

Figure 4.2: Assessing shifts in institutional capacity and market positioning



5. FUTURE DIRECTIONS: TOWARDS THE NEXT GENERATION OF PHYSICAL RISK AND OPPORTUNITIES ANALYSIS

This pilot project has built on TCFD guidance, to develop and test first-generation methodologies and climate change scenario inputs for banks to analyze physical risks and opportunities from climate change; but more work lies ahead. The process has demonstrated what can be achieved by banks based on existing research, evidence and capacities. It also highlights the improvements required to enable banks to deliver more robust assessments, and ultimately to facilitate physical climate-related disclosures which are systematic, consistent and repeatable, in line with the objectives of TCFD.

Research, analysis and collaboration, together with physical risk disclosures by companies across sectors, would improve the quality of banks' disclosures. The pilot project has identified the need to: access location-based client data; improve the quality and accessibility of climate-related datasets; integrate the macro-economic impacts of climate change; determine finance needs; and better understand the evolution of government adaptation policy, insurance products, premiums and markets. Banks will need to collaborate with various stakeholder groups to take this agenda forward effectively. Transparency and collaboration will enhance decision-making for all.

5.1. DEVELOPING IN-HOUSE DATA, ANALYSIS AND CAPACITIES WITHIN BANKS

Physical risk assessments can be improved by having granular data on borrowers, but these may not be available due to privacy rules or because they are not collected by banks. The banks in the Working Group highlighted several issues regarding data availability on borrowers which constrained the physical risk assessments. Access to borrower-level data can be restricted due to privacy rules, particularly for retail mortgages. Banks may also lack data on the locations and production characteristics for commercial borrowers. For instance, agricultural borrowers may have mixed farms, and banks are unlikely to know the contributions of crops, livestock, etc., to farm revenues. Banks can also lack facility-level data on commercial clients with multiple fixed assets. Banks piloting the methodologies used simplifying assumptions or external data sources to work around these challenges. Some banks undertook the analysis at a less granular spatial scale, to ensure privacy of data on individual borrowers; others anonymized their data on commercial real estate borrowers in order to utilize external platforms such as CatNet®. Banks piloting the energy sector methodology utilized data from specialist energy industry analysts and Bloomberg.

A deeper understanding of the historic relationships between climate-related events and PD and LTV ratios would be valuable. Some banks in the Working Group reported that some of their borrowers are already being affected by climate and weather events (e.g. impacts of droughts on borrower performance in the agriculture sector; impacts of extreme events on real estate property values). These provide early signals of the impacts of a changing climate, and empirical evidence which can be analyzed to improve the high-level estimates applied in the pilot project, and to calibrate forward-looking physical climate risk assessments based on scenarios. Spatial analysis of these correlations can help to pinpoint high-risk locations, which can then become the focus of more detailed analysis. Banks may also be able to identify trends in client behavior which provide evidence of investment by clients to manage existing climate-related risks. Such data can highlight growing market opportunities for banks to support climate resilience.

Banks can consider developing in-house capacities, platforms and tools to undertake spatial analysis, overlaying client data with climate-related data. Spatial analysis is essential for assessing physical climate-related risks and identifying opportunities. It helps find patterns in data and identify concentrations of risk (e.g. loan exposure in zones of high flood risk). Many banks do not currently have internal capacities to undertake these analyses and are more accustomed to using spreadsheet-based tools. Therefore, most banks in the pilot project utilized existing online spatial risk analysis tools and climate-related data portals, but found challenges in how these platforms interact with borrower data. For instance, platforms with global coverage may not provide the highest quality climate-related data available for specific countries; many climate-related data portals do not enable users to upload data on their borrowers, or bank's security and data protection protocols may not permit this. Banks that have in-house capacities for spatial analysis and advanced data analytics can overcome these issues and undertake higher-quality risk assessments. The benefits of having these capabilities are demonstrated by the Royal Bank of Canada (see Box 5.1). Banks can also work with analytics and advisory firms who are developing these platforms (see Section 5.3).

BOX 5.1: Royal Bank of Canada - Using spatial analysis to assess physical risks

RBC has invested in advanced internal location intelligence and data analytic capabilities. These capabilities are being used to help assess the impact of climate change on RBC's assets and its client portfolios. The benefits of building these capabilities internally include:

- **Improved spatial scale granularity:** RBC, like many other financial institutions, is exposed to risk through a wide variety of geographies, sectors, clients and asset types. While third-party climate risk mapping tools exist, these often provide insufficient and/or inconsistent granularity to assess the impact of natural events or incremental climate change. Precise longitude and latitude coordinates for assets (e.g., loans, collateral) and for other datasets greatly enhances the accuracy of physical risk analysis.
- **Protection and privacy of client data:** The protection of client data is critical for all financial institutions. The use of internally developed applications for conducting geospatial analysis provides RBC with the ability to protect the privacy and security of its client data.
- **Building empirical evidence:** While the frequency and intensity of natural events are expected to increase over time, assessing historical events to gain insights on how they impact clients and credit losses provides much needed data inputs for forward-looking analysis. With internal geospatial and data analytic capabilities, RBC can now analyze natural events that have occurred and assess the correlation of these events with factors such as property values and a borrower's probability of default. The outputs of this analysis can provide empirical evidence to inform and improve forward-looking climate change scenario analysis.
- **Data integration:** Diverse internal and external datasets must be combined in order to provide a robust and comprehensive analysis of the physical impacts of climate change. By developing and managing datasets and their analysis centrally, RBC has enhanced its ability to more deeply analyze the inter-relationship between multiple climate and client-related factors, or drivers.
- **Predictive analytics:** Conducting climate change scenario analysis requires the use of vast and complex internal and external datasets, making it ideal for the application of machine learning and well-suited to the development of predictive analytics.

To undertake comprehensive assessments of physical risk, banks need to establish multi-disciplinary teams and dedicate sufficient resources. Teams involved in piloting the methodologies from the Working Group of banks included professionals from: sustainability, environmental and social risk, credit risk, stress testing, rating methodologies, portfolio management, subject matter experts/industry specialists and client-facing business teams. Specialist review was required at all steps to determine appropriate inputs and review outputs from application of the methodologies. Such groups need to be given a clear mandate and time/resources to work on the assessments.

5.2. STRENGTHENING THE RESEARCH BASE

Banks could benefit from improved collaboration with the climate and economic research community to target needed improvements to the evidence base underpinning physical risk assessments. Key areas for development are improved spatial data on future changes in incremental and extreme climate-related events, and more granular impact model data (e.g. impacts on crop yield). Through piloting the physical risk methodologies, a number of banks in the Working Group have made connections with researchers who can do this work, and now there is an industry demand for the information. Further research is also needed on the macro-economic impacts of physical climate change.

Datasets that provide full distributions of extreme events would be valuable for banks' analysis of their impacts. One of the current limitations with the extreme events analysis for flood and cyclone is that by analyzing specific return periods as provided in online data portals (e.g. 1 in 100 year, or 1 in 200 year flood), banks are only sampling discrete points from the full distribution of return periods. This could lead to an underestimation of the risk facing borrowers. For example, if a mortgaged property is located in an area exposed to a 1 in 105 year flood, this will be highlighted on the 1 in 200 year flood map, but will not feature on the 1 in 100 year map. The available data may also underestimate the impact of flash droughts and long-term droughts, and further research in this area would be useful.

Further research and analysis should focus on providing spatial data on future changes in extreme events. As discussed in Section 2.3, the approach in the pilot physical risk methodologies has involved a two-step process of firstly, using data portals to provide baseline (present-day) return periods or frequencies based on historical records, and then to draw upon research and models to estimate how these may change in the future. A better approach would be for banks to have access to web-based spatial datasets that provide future changes in the frequency of extreme events. One such example is the Global Drought Risk product developed by Princeton Climate Analytics (as described in Box 2.3 in Section 2.3). It is important that the assumptions and limitations with these datasets are clearly articulated.

More research is needed to reduce uncertainties about the scale of the macro-economic impacts of climate change and physical risk. At present, macro-economic modeling approaches provide a wide range of estimated impacts on GDP. Furthermore, there is very little research on how physical climate change will affect broader macro-economic indicators such as inflation and interest rates. While they could be significant, macro-economic impacts are not therefore included in the pilot project methodologies. These knowledge gaps and future research needs are further discussed in Box 5.2.

BOX 5.2: The macro-economic impacts of climate change and physical risk to banks' income and balance sheets

Authored by Vivid Economics

What are the macro-economic impacts of physical climate risks?

Economists have been modeling the impacts of climate change at the level of national/regional economies and the global economy for some 30 years. However, there remain large disagreements and uncertainties about the size and, in some cases, even the sign of the impacts, but all studies agree that climate change affects the aggregate output of goods and services (i.e. GDP) by directly damaging and destroying output, for example crop losses during drought, by damaging or destroying factors of production, for example factories and transportation infrastructure, or by reducing (or sometimes boosting) factor productivity.[24]

Though it has been much less studied, the fact that climate change effectively acts as a supply-side shock means that it also has the potential to cause supply-side inflation, if other prices in the economy, such as wages, are slow to adjust. This inflationary effect may be particularly severe after an extreme weather event.[25-26] On the other hand, climate fluctuations may lead to demand-side deflationary pressure, again particularly in the case of extreme weather events that may impair the smooth functioning of financial systems and otherwise induce consumers to spend less. In turn, depending on the monetary policy regime, unanticipated inflationary effects from climate change may result in a change in real interest rates.

In addition, there is wide agreement that the impacts of climate change will vary across countries, depending on (i) their physical exposure, for example their average temperature and rainfall, their temperature and rainfall variability, and their exposure to sea level rise via low-lying coasts, as well as (ii) their socio-economic sensitivity to climate change and (iii) capacity to adapt.[24] Differential impacts on GDP, GDP growth, inflation and interest rates mean that climate change may affect exchange rates, as well as other aspects of countries' trade positions.

There is also reason to suppose that climate change may affect the equity risk premium in different parts of the world[27-28] through affecting the overall volatility of economic growth, correlations between the returns on risky assets and overall economic growth, or investors' level of risk aversion. Like climate change impacts on inflation and monetary policy, research on this topic is still in its infancy.

While these mechanisms are undisputed in principle, the large remaining uncertainties about their magnitude pose a barrier to factoring them into assessments of banks' physical risk at this time. Moreover, there is a lack of practical, empirical understanding of how high-level macro-economic impacts affect banks' level of risk. Together this means that quantifying physical risk to banks' activities that specifically derives from macro-economic impacts of climate change cannot be reliably done at this time. This may be contrasted with transition risk and the macro-economic impacts of efforts to reduce greenhouse gas emissions, where there are also large uncertainties, but where the evidence base is generally fuller and of better quality and where the projections of energy systems models may be used with greater confidence.

What methods have been used by economists to estimate the macro-economic impacts of climate change?

Economists have broadly taken three different approaches to estimating the macro-economic impact of climate change.

The first and oldest is often referred to as the 'enumerative' approach. It involves reviewing physical impact modeling across a range of sectors that typically includes agriculture, coastal zones, energy and water; obtaining from these studies quantified responses in physical terms such as reduced crop productivity per degree Celsius warming; and then multiplying these response 'elasticities' by prices to quantify the eventual economic cost.[29-30] The main advantage of this approach is that it allows the inclusion of so-called 'non-market' economic impacts, for example those on natural ecosystems and human health, but these are not directly relevant in the context of banks' risk management, because they do not immediately affect GDP or other relevant macro-economic variables. The disadvantages of the approach include limited empirical evidence to inform many aspects of these studies, as well as the possibility that the fundamental assumption that impacts can be added together or enumerated across sectors does not hold.

A second approach involves adapting computable general equilibrium (CGE) models, originally developed by economists primarily to investigate trade issues, to studying the physical impacts of climate change.[31] These are simulated as supply-side shocks and the advantage of the approach is that it incorporates all the possible linkages between different sectors, addressing the main shortcoming of the enumerative approach. The main disadvantage is similar to the enumerative approach in that the calibration and validation of these models has a limited empirical base.

The third approach is avowedly empirical and uses variation in observed climatic conditions to statistically estimate the effect on observed macro-economic outcomes, principally GDP. The main advantage, especially of more recent studies that comprise many countries and many years (panel data),[32-33] is their plausible identification of cause (climate) and effect (a change in the macro-economy). The main disadvantage is that the effects of past climate fluctuations, generally on short timescales such as annual, may not be a good proxy for future incremental climate change.

There is also a large body of case studies of the economic impacts of extreme climate and weather events, such as droughts, floods and windstorms.[34]

What are the main results of macro-economic impact assessments to date?

Most research on the macro-economic impacts of climate change has been geared towards estimating the social cost of carbon emissions. This requires understanding the costs of the physical impacts of climate change with a view to answering questions about the economically efficient level of climate change mitigation. It has therefore focused almost exclusively on physical impact costs as a percentage of GDP as an outcome. However, this type of analysis is only of limited help in quantifying financial risk or answering broader questions that investors and other financial institutions might have.

The impacts of a changing climate on GDP can be both negative and positive, not only in particular country-sectors, but in all likelihood for whole national economies too. This makes it more of an open question what sign the impacts take when aggregated to large regions and indeed to the global level, but most studies estimate a negative impact on GDP, especially in developing countries.[35]

Until recently the consensus among modelers from all three approaches set out above was that 2.5-3°C warming above the pre-industrial global average temperature, (a level we might expect to reach without significant emissions reductions sometime in the second half of this century), would reduce global GDP by around 1-3% relative to a counter-factual scenario with no climate impacts (i.e. this constitutes a much smaller impact when expressed in terms of growth rates).[35] The same modelers were in much less agreement about what higher temperature increases would entail, with some relatively optimistic and others pointing to increasing losses, arising perhaps from tipping points in the climate system.[36]

CGE modeling, while producing overall estimates within this range, has showed that general-equilibrium economic effects, principally relative price changes, can help economies adapt to climate change by efficiently reallocating activity, thereby reducing the overall impact compared to first-round effects. For example, if climate change affects energy production, thereby making energy more expensive, the overall economic cost can be reduced if energy consumers substitute energy with other inputs whose relative price has fallen (e.g. investing in more energy efficient capital).

By contrast, recent studies using panel data to estimate the observed statistical effect of climate fluctuations on GDP growth have found very large impacts on growth.[33] If the estimated effects are then applied to climate change in the future, they suggest impacts on GDP that are an order of magnitude higher (e.g. up to 25% of global GDP for 2°C warming) and would undoubtedly have large implications for many aspects of the macro-economy. These studies also suggest considerable regional variation: one study suggests 4°C warming could lead to GDP declines of around 75% in Sub-Saharan Africa, South Asia and South East Asia, compared to increases in GDP of 50% in Europe, by 2100.[33]

In general, the level of confidence in any existing estimates of the macro-economic impacts of climate change is low. Each approach to estimating these impacts has different strengths and weaknesses. In addition, all are challenged with modeling a set of climatic conditions never before experienced (our understanding of when climate tipping points may be triggered and what the consequences would be is virtually non-existent, for example), and, whatever approach is taken, there are further climatic uncertainties, such as the overall degree and rate of warming, which have to be factored in.

How could the macro-economic impacts of climate change affect the risks facing banks?

The macro-economic impacts of climate change could affect various categories of risk facing banks, but most obviously credit and market risk.

Credit risk tends to be assessed at the level of individual loans on the basis of risk factors that include credit and repayment history, as well as current and forward-looking indicators. In this context, the macro-economic impacts of climate change might be an indirect risk factors for individual assets/loans. This would be in addition to the assessment of direct impacts of climate change on borrower credit risk by means of detailed modeling at higher sectoral and spatial resolution, as per the methodologies applied in the pilot project.

For example, extreme weather events could result in damage to the assets of, and/or business interruption to, a company in receipt of a bank loan, but in addition to these direct impact channels the broader macro-economic environment, including levels of inflation, consumer spending and other factors, could also affect the ability of the company to repay the loan. At the bank level rather than the level of individual loans, credit risk is clearly also affected by portfolio considerations with regard to the banking book, i.e. the relationship between credit risk to different loans.

The macro-economic impacts of climate change could also affect bank's market risk, which includes interest rate risk and broader sources of market risk to assets held in banks' trading books. These broader sources of market risk to banks' assets include equity risk, commodity risk and currency risk.

There is an urgent need for more research into the links between the macro-economic impacts of climate change on the one hand, and credit/market risk to banks on the other hand. What little research exists has focused on physical risk to equity portfolios, which affects banks' market risk through their asset holdings. Even here, the initial forays into the effects of climate change on equity portfolios has been very broad-brush, for example estimates of Value at Risk for a fully diversified portfolio of global equities under stylized scenarios.[37] More research is needed into this impact channel, and foundational research is required when it comes to credit risk, interest rate risk, commodity, and currency risk.

5.3. DEVELOPING ANALYTICAL PLATFORMS AND TOOLS TO SUPPORT PHYSICAL RISK AND OPPORTUNITIES ASSESSMENTS

Analytics and advisory firms can further improve platforms and tools for banks to assess physical risks and opportunities in portfolios. Platforms for spatial analysis are beginning to emerge, such as Bloomberg MAPS which was applied by two of the Working Group banks to assess physical risks in their utilities portfolio (see the case studies in Chapter 3). This geospatial tool provides efficiencies through its ability to overlay and analyze multiple datasets, bringing together geographic data on extreme events and incremental climate change impacts with locations of borrowers' facilities and corresponding baseline financial and production data. The ability to visualize spatial data also helps to pinpoint concentrations of risk and facilitates discussions with internal and external stakeholders. These platforms should be improved to incorporate additional sectors and data on changing climate risks. They should also support more sophisticated analysis of physical risks and opportunities in borrower's value chains (covering supply and demand). On the supply side, risks include interruption of raw materials and other inputs, and disruption of distribution networks. These were exemplified by the 2011 flood in Thailand, which disrupted over 14,500 companies worldwide at a total economic cost of $45 billion.[38] Demand-side risks and opportunities include changes in markets, such as consumer staples and energy requirements for heating and cooling.

There is a requirement for more comprehensive market assessments of adaptation investment needs for sectors and countries, and specifically the scale and timing of demand for finance support from banks. Market assessments can help banks identify opportunities to support clients by financing their adaptation investments. They also improve the quality and realism of physical risk assessments. Due to a lack of available market assessments, the pilot physical risk methodology for agriculture and energy evaluates changes in PD solely on the basis of impacts on revenues and COGS. It assumes that borrowers do not make investments to adapt to these impacts. This is clearly an unrealistic picture of what is likely to happen. Direct communication with borrowers on these topics, as highlighted below, would provide even better data.

5.4. IMPROVING INFORMATION FLOWS ON PHYSICAL RISK AND ADAPTATION BETWEEN BANKS AND BORROWERS

Banks would benefit from disclosures by borrowers on their physical climate risk assessments and adaptation investments. Some companies in climate-sensitive sectors have undertaken climate change risk assessments, developed adaptation plans, and invested in adaptation measures. Disclosure by companies of the findings of their risk assessments and adaptation investments (whether planned or implemented) will help banks to more accurately evaluate the risks in their loan portfolios. It will also help banks to identify opportunities to support clients making these investments by providing finance. Improved disclosures by corporates over time, in line with TCFD recommendations, will begin to build an evidence base to facilitate this information exchange.

5.5. IMPROVING DIALOGUE WITH GOVERNMENTS AND INSURERS

Governments provide essential risk mitigation measures against extreme events and incremental climate change impacts, such as flood defenses, climate-related standards for infrastructure, disaster risk management systems, and financial backing of insurance schemes. They also publish hazard maps (e.g. for flood risk) which guide spatial planning decisions and influence insurance and property values. Furthermore, governments provide the overall national vision, strategy and plan for climate change adaptation, and may require stakeholders (including companies) to take adaptation-related action. Government policy and regulation in these areas can therefore have profound impacts on banks' borrowers. Understanding how governments are adapting to climate change will help banks assess physical climate risks to their borrowers.

The insurance industry has been vocal on climate change for decades; however, it is unclear how insurance availability and pricing may change in the future, as climate change intensifies. The pilot project found that there is little publicly-available data on present-day insurance uptake for commercial sectors (though more data are available for real estate and agriculture). It is also challenging to evaluate how the insurance market may change due to climate change, and the implications for property values. Research on these topics is summarized in Appendix B: Findings of research on insurance. Bearing in mind these uncertainties, the pilot project methodologies exclude insurance as a risk mitigant for borrower losses from extreme events. Engaging in regular dialogue with insurance providers will help banks to better understand these issues.

5.6. CONCLUDING REMARKS

These proposed improvements for next generations of physical risk and opportunity assessments would facilitate mainstreaming of physical climate risk and opportunities analysis within banks. The pilot project has laid the foundations for this ongoing process, and the Working Group banks have already made important steps forward. Future iterations of the methodologies will help to ensure that physical risk and opportunity analysis is embedded into banks' decision-making and receives the strategic attention that it deserves.

APPENDIX A: ACRONYMS

AgMIP	Agricultural Model Intercomparison and Improvement Project
AR5	Fifth Assessment Report of the IPCC
BAU	Business-as-usual
CapEx	Capital Expenditure
CDP	Carbon Disclosure Project
CGE	Computable General Equilibrium
CMIP5	Coupled Model Inter-comparison Project Phase 5
CRE	Commercial Real Estate
CVRA	Climate Vulnerability and Risk Assessments
EBRD	European Bank for Reconstruction and Development
FLOPROS	An evolving global database of FLOod PROtection Standards
GCECA	Global Centre for Excellence on Climate Adaptation
GDP	Gross Domestic Product
IPCC	Intergovernmental Panel on Climate Change
IPRE	Income Producing Real Estate
LTV	Loan-to-Value
MPCI	Multi-peril crop insurance
MSL	Mean Sea Level
MSMEs	Micro, Small and Medium Enterprises
NAP	National Adaptation Plan
NDC	Nationally Determined Contribution
OpEx	Operational Expenditure
PCA	Princeton Climate Analytics
PD	Probability of Default
PGF	Princeton Global Forcing
RCP	Representative Concentration Pathway
RWA	Risk-weighted asset
SMEs	Small and Medium-sized Enterprises
TCFD	Task Force on Climate-related Financial Disclosures
VIC	Variable Infiltration Capacity
UNEP FI	UN Environment Finance Initiative

APPENDIX B: FINDINGS OF RESEARCH ON INSURANCE

INTRODUCTION

Insurance is an important climate risk management tool, allowing households, businesses and governments to transfer climate risks to reduce the short and long-term losses associated with extreme climate-related events. With the increase of weather and climate-related losses and damages around the world in recent decades, the insurance industry's ability to continue to provide coverage is an important consideration for managing climate risks in the future.

In order to investigate how current and future insurance provision could help mitigate against the risks of extreme events on loan portfolios, research[x] was undertaken on two main questions:

1. What is the extent of present-day insurance coverage for extreme events in sectors of interest?
2. What could happen to future insurance provision (e.g. premium charges, excesses, exclusions) where climate change leads to increased damage from extreme events in the future?

The research covered three main categories of commercial property insurance: property damage, contents damage and business interruption; supply chain or non-damage business interruption (NDBI)[39] insurance; to sector-specific insurance, e.g. crop insurance (agriculture sector).

KEY FINDINGS

Country-specific and publicly available data on current insurance coverage held in different commercial sectors is very sparse. Regulators and industry associations in most countries were not able to provide this information. The most detailed information was obtained for France, where 100% of businesses have property insurance and around 50% have business interruption coverage (this was assumed to be lower than 50% for agriculture); data for other types of insurance was not available.[y] In Australia, it was speculated that the proportion of companies (large corporations only) with insurance coverage across most sectors is "high".[z] Some global survey-based data is available; for example, a 2016 survey of 526 companies in 64 countries showed that 43% did not insure their supply chains at all.[40] Another study stated that contingent business interruption insurance coverage is low worldwide, though without providing any data.[41]

Some sector-specific data are available for the real estate and agriculture sectors. Information provided by banks confirms that for real estate mortgages, property insurance is mandatory by banks and/or governments in many countries (although if insurance lapses banks may not be aware of it). The hazards that are typically included in the coverage differ from country to country. For example, in the UK, standard home insurance policies include flooding but, in the USA, flooding is excluded and must be purchased separately. In the agriculture sector, a few countries have nationally-regulated agricultural insurance schemes, in some cases subsidized by the government. For example, 90% of insurable farmland in the USA is covered by the federal government's multi-peril crop insurance scheme (MPCI), which provides subsidies.

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x. Research comprised extensive literature review, collaboration with UNEP FI Principles for Sustainable Insurance (PSI)'s team to consult with national insurance regulators and industry associations in all countries of interest to the project, and one-to-one phone interviews with key industry and academic experts in the climate risk insurance field.

y. Based on Fédération Française de l'Assurance (FFA)'s response to a request for information via UNEP FI PSI.

z. Based on Australian Prudential Regulation Authority (APRA)'s response to a request for information via UNEP FI PSI.

Looking to future insurance coverage, a wide range of demand- and supply-side factors influence an insurer's decision to provide coverage; understanding how climate change will influence those factors is a significant challenge. Relevant factors on the supply side include: understanding of the risk(s), access to capital, market conditions, regulation and estimated losses. On the demand side, wealth, willingness to pay for insurance and new policy and regulation play a role.[42] All of these factors, which are interlinked, may be impacted by climate change. For example, a new regulation on solvency or disclosure requirements in response to increased climate risk may impact insurers, as well as businesses looking to purchase insurance.

Insurers have narrowed or withdrawn coverage following climate-related events in the past. There is little published literature examining the extent to which insurance coverage (and premiums) may change due to future climate change. There are a few published studies[43] but further research is needed. However, there is some empirical evidence that increasing severity and frequency of climate-related hazards has limited the supply of insurance in the past. A 2012 study[44] investigated the impact of natural disasters and regulation on the supply decisions of US property insurers and found that, for homeowners' insurance, insurers are more likely to reduce their coverage in response to unexpected severe events. There are also case studies around the world where insurers have narrowed or withdrawn coverage from certain markets or for certain climate hazards. Selected examples include:

- **Caribbean:** In 1992 after Hurricanes Andrew and Iniki hit the USA and the Caribbean, the insurance industry increased reinsurance costs and significantly decreased coverage. The Hawaiian Insurance Group stopped trading and announced the non-renovation of existing policies, which had cascading impacts causing other insurers to withdraw from the Pacific and Caribbean island countries.[45]
- **Ireland:** Though Ireland has 98% flood insurance penetration, there is evidence of coverage gaps and increasingly unaffordable rates, for example in Cork. A lack of data means that it remains unclear to what extent flood insurance is actually available or being refused in high-risk areas, but there are reports of premiums rising to unaffordable levels and terms and conditions being imposed, such as deductibles, that would render flood insurance unviable for owners of homes or businesses.[46]
- **Australia:** In 2012, Suncorp insurance company refused coverage to householders in two Queensland towns that had experienced flooding on several occasions in the previous few years. Coverage was reinstated following the construction of flood protection works, illustrating the importance of establishing risk reduction measures.[47]
- **Global:** After the Thai floods of 2011, which disrupted global supply chains, many large multinational corporations lodged contingent business interruption claims with their insurers and reinsurers, which cost Lloyd's of London US$2.2 billion. Since this incident, insurers and reinsurers have adopted practices such as exclusions and increasing prices in order to mitigate the risks presented by such indirect impacts.[48]

These case studies give an indication of how insurance markets may react in future to increasing levels of physical risk leading to exceedance of anticipated losses. They may decrease coverage or withdraw from certain markets, as well as increase premiums to unaffordable levels.

Where the affordability or insurability of risks is threatened, there may be a case for government intervention to ease the burden of rising insurance premiums.[49] In some cases, the government has already stepped in to provide insurance coverage where the market has failed. For example, the USA's National Flood Insurance Program (NFIP) involves government support to the market to make flood insurance more affordable. In the UK, the Flood Re scheme is a not-for-profit insurance pool implemented by the insurance industry with government oversight that aims to make affordable flood insurance more available.

CONCLUSIONS

Research has shown that publicly available data on insurance uptake across commercial sectors and regions are scarce and there is no consensus regarding future insurance provision under climate change. This was confirmed by responses from banks, national insurance regulators and industry associations, as well as insurance industry experts. Looking to the future, this lack of present-day data, combined with the fact that there are numerous interrelated factors that influence insurers' decisions to provide coverage (beyond changing climate hazards), make it challenging to develop robust estimates of how insurance coverage will change under climate change. Given the current lack of data and consensus, improved engagement between banks, borrowers, and the insurance industry will help banks to understand the extent of existing insurance coverage held across their lending portfolios, to assess government and bank-level insurance requirements, and to consider where insurers have narrowed or withdrawn coverage in the past in geographies/sectors of interest. This will ultimately help improve transparency and the quality of forward-looking disclosures.

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