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Nature-Related Financial Risks in Brazil

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Abstract

Biodiversity loss and associated economic costs are increasingly recognized as a source of financial risks. This paper explores how and to what extent Brazilian banks are exposed to the loss of biodiversity through their lending to non-financial corporates. The results suggest that such exposures are material. Forty-six percent of Brazilian banks' non-financial corporate loan portfolio is concentrated in sectors highly or very highly dependent on one or more ecosystem services. Output losses associated with the collapse in ecosystem services could translate into a cumulative long-term increase in corporate nonperforming loans of 9 percentage points. Moreover, 15 percent of Brazilian banks' corporate loan portfolio is to firms potentially operating in protected areas, which could increase to 25 percent should conservation gaps close, and 38 percent should all priority areas become protected. Finally, 7 percent of corporate loans are to firms for which environmental controversies have been recorded. While preliminary, the results have important policy implications for both Brazilian banks and Banco Central do Brasil.

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Nature-Related Financial Risks in Brazil

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1. Introduction

Biodiversity loss is one of the greatest threats to humanity (WEF 2021). All societies depend on nature for their very survival, but nature is declining faster than at any time in human history (IPBES 2019). The decline in global wildlife populations coupled with the massive degradation of oceans, forests, freshwater bodies and other ecosystems is undermining nature's ability to provide vital goods and services (so-called ecosystem services) for all societies to thrive. This is negatively impacting nature's resilience and adaptability, undermining its productivity and fueling risks to its goods and services (Dasgupta 2021).

The COVID-19 pandemic is a stark reminder that planetary health and human health are deeply intertwined. While the specific origins of the COVID-19 outbreak and its transmission pathway are yet to be ascertained, environmental degradation may well have played a crucial role. Several studies (see, for example, Olivero and others 2017; and Gibb and others 2020) have shown a link between natural habitat destruction and greater risk of zoonotic diseases. Deforestation and land-use conversion, largely driven by agricultural expansion, significantly increase the risk of zoonoses (Dobson and others 2020), exacerbating biodiversity loss (IPBES 2019) and accelerating climate change (IPCC 2018). Deforestation, together with agriculture and other land use changes, is responsible for roughly a quarter of global greenhouse gas emissions (IPCC 2019).

Biodiversity loss can have significant consequences for the global economy. Over half the world's total GDP is moderately or highly dependent on nature and its services, with construction, agriculture, and food and beverages the three sectors that depend most on nature (WEF 2020). Given that economies are "embedded" within nature (Dasgupta 2021), the loss of ecosystem services such as fertile soil, flood protection and erosion control can result in severe losses and disruptions to economic activity. Should the loss of ecosystem services continue unabated, the associated economic costs could be significant. For example, under a business-as-usual scenario, the decline in four ecosystem services – pollinators, forestry production, marine fisheries, and carbon sequestration by forests – could lead to losses in global real GDP of US$90 billion by 2030, which could increase by a factor of 2.5 if climate change damages linked to the loss of ecosystems are factored in. In a low probability, high impact scenario of collapse in ecosystem services, global real GDP could decrease by US$ 2.7 trillion or minus 2.4 percent compared to the baseline (World Bank, 2021).[2] Low-income economies, which are highly dependent on the services provided by nature, stand to lose the most from biodiversity loss.

Biodiversity loss and associated economic costs are a source of financial risks. The relationship between biodiversity and the financial sector can be characterized by "double materiality". On the one hand, changes in the stock and condition of natural capital alter its ability to provide the goods and services upon which businesses depend, and therefore have implications for the risk

[2] Estimates on the economic costs of biodiversity loss are subject to several uncertainties. Despite progress, knowledge of the interaction between ecosystem services and the economy remains limited, and it is very difficult to quantify the impact of biodiversity loss on the supply of ecosystem services due to the numerous non-linearities at play. Nonetheless, the economic impact of biodiversity loss can be severe.

assessment of their operations and profitability. On the other hand, financial institutions can have adverse impacts on biodiversity and ecosystem services through their operations and investment decisions (OECD 2019a; DNB 2020).[3] All this can translate into traditional credit risks, market risks, operational risks and liquidity risks for financial institutions, with negative feedback loops to the economy (Figure 1). The potential for several nature-related risks can also have systemic implications because of the complexity, interdependence and interconnectedness within the financial system (NGFS 2019; Bolton and others 2020).

Biodiversity loss can impact the financial system through two main channels (NGFS-INSPIRE 2021). The first is nature-related physical risks, which refer to the financial impact of changes in natural capital. Loss and degradation of ecosystem services can damage fixed assets and infrastructure, and disrupt supply chains and business operations, causing losses for businesses and ultimately for financial institutions. Physical risks can be acute such as disruption from infectious diseases, or chronic such as reduced suitability of land for crop cultivation. The second channel is nature-related transition risks, which result from the process of adjustment towards a more sustainable economy. Losses originate from societal change, and can be triggered, for example, by the adoption of biodiversity-related regulation and policy, technological progress, shifts in market sentiment and preferences, litigation, and reputational damage. The transmission of these risks to the financial sector is subject to significant uncertainty. While some progress has been made at the conceptual level on measuring the impact of the financial sector on biodiversity (see, for example, Berger and others 2018, and, for an overview of best practices, OECD 2019b), the estimation of financial exposures to the risks of biodiversity loss remains largely unexplored in the literature.

Against this background, this paper aims to provide descriptive evidence on the exposure of the Brazilian banking sector to biodiversity loss. Brazil is the most biologically diverse country in the world.[4] It is estimated that the country hosts between 15-20 percent of the world's biological diversity, with the greatest number of endemic species on a global scale. Biodiversity in Brazil is threatened by, among others, deforestation and climate change. Despite the region's significant influence on the global climate, the Amazon Basin remains endangered by deforestation associated with increasing settlement and expanding agricultural, ranching, logging, and mining operations, which may soon be reaching a "tipping point" if action is not urgently taken (Lapola and others 2018).[5] Brazil was one of the first South American countries to fully approve a National Biodiversity Strategy in 2006, and in 2013 it adopted the 2020 biodiversity targets aligned with the UN Aichi Biodiversity Targets, including the establishment of ecological corridors, mosaics of protected areas, and sustainable forest management. Despite progress in some areas (e.g., tropical vegetation restoration), Brazil has lagged in terms of, for example, subsidies for

[3] This concept of "double materiality" has been used by the European Commission in its 2014 Non-Financial Reporting Directive to encompass both financial materiality (impacts from the external world on the financial value of a company) and environmental and social materiality (impacts of the company's activities on the external world).
[4] See https://www.cbd.int/.
[5] "Tipping points" refer to critical thresholds in an ecological system that, when exceeded, can lead to a significant change in the state of the system, and prevent the system from returning to its former state.

production of commodities linked to forest destruction (which exceed by a factor of 100 or more the amount spent on measures to combat deforestation) and the deforestation rate, with improvements in the Amazon biome being undone in recent years (CBD 2020).[6] It is expected that new targets will be committed following the UN Convention on Biological Diversity (CBD) in October 2021 (COP15), which has the objective of increasing the extent of protected areas, promoting the sustainable use of ecosystems and lessening the causes of biodiversity loss.

Given the potentially significant macrofinancial implications of biodiversity loss in Brazil, it is important that both banks and Banco Central do Brasil (BCB), the central bank, build the capacity to understand and in time manage the risks associated with the loss of biodiversity. As the Dasgupta Review of the Economics of Biodiversity notes, the "financial system is critical to supporting a more sustainable engagement with nature" (Dasgupta 2021). Brazil's financial system is bank-based, with banks' assets accounting for about two-thirds of total financial system assets. Therefore, banks can play a pivotal role in managing and mitigating the risks and uncertainty resulting from the unsustainable engagement with nature. At the same time, BCB, within its mandate to ensure a solid and efficient financial system, has an interest that banks address nature-related risks adequately and proactively, learning and building on the advances on climate-related financial risks. Leveraging on its participation in the Central Banks and Supervisors Network for Greening the Financial System (NGFS), BCB is implementing a sustainability agenda as a part of its institutional work program, which could give renewed emphasis to nature-related financial risks.[7]

This paper explores how and to what extent Brazilian banks are exposed to the loss of biodiversity through their lending to non-financial corporates. First, we describe the extent to which the banking sector is indirectly dependent on ecosystem services, which is our proxy for physical risks. Using the ENCORE database, which details and assigns a score on the dependencies on 21 ecosystem services for 86 business processes, we link the latter with economic sectors and then we determine bank credit exposures to those sectors using BCB data. This gives us evidence of Brazilian banks' exposure to sectors that are highly or very highly dependent on one or more ecosystem services. Second, we describe the extent to which Brazilian banks finance companies that potentially operate in protected areas and priority areas for biodiversity conservation, and that are involved in environmentally controversial activities. This is the proxy we use to measure transition risks. Based on *Relação Anual de Informações Sociais* (RAIS) and BCB data, we first map bank loan exposures at the municipal level. In a further step, we merge those geographical exposures with data from the World Database on Protected Areas and the Brazilian Ministry of Environment to determine banking sector loans to companies in protected or priority areas as determined by the Brazilian authorities. Finally, we use the MSCI ESG Controversies database to

[6] According to country's national space research agency INPE, in the first half of 2020 deforestation was up 25 percent, for a total 1,184 square miles, compared to the same period in 2019, on track to be the worst year for deforestation in more than a decade. See http://www.inpe.br.
[7] See https://www.bcb.gov.br/en/financialstability/sustainability.

identify Brazilian firms for which environmental controversies have been recorded, and merge that information with bank loan data from their annual reports.

The key results of this paper are as follows. Brazilian banks have an outstanding credit exposure of BRL 811 billion to non-financial corporates that operate in sectors highly or very highly dependent on one or more ecosystem services. This amount represents 46 percent of the total non-financial corporate loan portfolio and 20 percent of the total credit portfolio, and is slightly tilted to firms that receive government-subsidized resources (so-called earmarked credit). The highest dependence is on the ecosystems that provide climate regulation, ground water and surface water. Based on historical sensitivity of Brazilian banks' asset quality to macroeconomic conditions (see Vazquez, Tabak, and Souto 2012) and macroeconomic modeling of ecosystem services (World Bank, 2021), the GDP losses associated with the collapse in ecosystem services could translate into a cumulative long-term increase in corporate nonperforming loans (NPLs) in the order of 9 percentage points, other things being equal. Brazilian banks also have an outstanding loan exposure of BRL 254 billion or 15 percent of their corporate portfolio to firms potentially operating in protected areas. Such an exposure could increase to BRL 437 billion (25 percent of the corporate credit portfolio) should conservation gaps close, and to BRL 664 billion (38 percent of the portfolio) should all priority areas become protected.[8] Finally, for the 11 of 143 Brazilian listed firms for which environmental controversies have been recorded, as of December 31, 2019, banks had an outstanding loan exposure of BRL 109 billion (7 percent of the corporate credit portfolio).

To the best our knowledge, this paper is the first to attempt quantifying bank exposures to biodiversity loss in an emerging market and the second to do so in the relevant literature. The only paper we are aware of that explores biodiversity risks for the financial sector is the pioneering work by De Nederlandsche Bank (DNB 2020), the Dutch central bank. DNB (2020) estimates the exposure of Dutch financial institutions – banks, insurance companies and pension funds – through debt and equity instruments to risks resulting from the loss of biodiversity, both domestically and internationally, and finds that those exposures are material. Dutch financial institutions have invested a total of € 510 billion (36 percent of the total portfolio) in companies that are highly or very highly dependent on one or more ecosystem services, and are therefore exposed to physical risks if one or more of these services are disrupted or lost. Moreover, the Dutch financial sector is exposed to transition risks through € 28 billion in companies that operate in areas that are protected or that might come under protection and € 96 billion invested worldwide in companies involved in environmental controversies. This paper builds upon DNB (2020) and though it more narrowly focuses on banks and their domestic exposures to biodiversity loss through lending activities, it extends DNB (2020) in two directions. First, this paper estimates the impact on Brazilian bank NPLs of the loss of ecosystem services. Second, it measures transition risks by relying on the Brazilian government's plans with regard to biodiversity conservation areas, as opposed to scenarios for the expansion of protected areas.

[8] Conservation gaps refers to those areas which are not currently protected and are classified as areas of very high priority actions for biodiversity conservation.

The latter entails a significant degree of uncertainty as the designation of protected areas usually results from extensive decision-making involving an ample spectrum of stakeholders.

This paper aims to contribute to the growing interest among central banks and supervisors on the impact of biodiversity loss on the financial sector. Significant progress has been made on identifying and measuring the financial risks arising from climate change (see, for example, Bank of England 2018; DNB 2019; Banque de France 2021), especially since the NGFS has spearheaded these efforts. However, only recently have central banks and supervisors recognized the need to extend their focus from climate change to the challenges of addressing the implications of broader nature-related risks and the conservation of nature and biodiversity. To that end, the NGFS has launched a study group on biodiversity and financial stability, which has the objective to advance our collective understanding of the impact of finance on the provision of key ecosystem services as well as the consequences of biodiversity loss for financial stability.[9] Ultimately, the aim is to establish an evidence-based approach to how central banks and supervisors could fulfill their mandates in the context of biodiversity loss. This paper aims to be a step in that direction and points to the importance for banks and BCB to advance their understanding of the financial risks associated with the loss of biodiversity.

The remainder of this paper is organized as follows. Section 2 presents the methodology and the data used for the analysis. Section 3 discusses the key results while section 4 concludes.

2. Methodology and data

This section presents the methods and the databases used to estimate Brazilian banks' exposure to the physical and transition risks associated with the loss of biodiversity. Our methodology for analyzing physical risks is twofold. We first gauge the extent of the banking sector's potential exposure to reduced availability of ecosystem services. Second, we provide preliminary estimates of the impact on banks' NPLs in a collapse of ecosystem services scenario. We tackle transition risks from two different angles too. First, we employ spatial methods to determine loan allocation in protected areas and priority areas for biodiversity conservation. Then, we gauge the banking system exposure to firms with a negative impact on the environment.

Information from different sources is combined to size the potential impact of nature-related financial risks in Brazil. Data constraints narrow the scope of our analysis to the domestic exposure of banks to biodiversity loss through lending activities. Rather than analyzing the entire spectrum of financial institutions, we focus on the banking sector only, which represents about two-thirds of the total financial system assets in Brazil. Table 1 presents a summary of the data employed in the analysis.

[9] See https://www.ngfs.net/en/communique-de-presse/ngfs-and-inspire-launch-joint-research-project-biodiversity-and-financial-stability.

Physical risks

Loss of ecosystem services

The banking sector is exposed indirectly to physical risks by providing credit to enterprises whose production processes depend on ecosystem services. To assess this exposure, we determined the amount of credit that Brazilian banks allocate to firms with business processes dependent upon ecosystem services. We relied on the ENCORE database, which provides a list of 86 different business processes that directly depend on 21 ecosystem services (see Table 2).[10] We followed the methodology laid out in DNB (2020) to link our data on banks' credit portfolio by economic sectors (e.g., agriculture) with their associated production processes (e.g., rainfed arable crops).[11] Furthermore, to determine which ecosystem services might be more critical to production processes and which potential impacts might be of greatest concern for banks, we leveraged on ENCORE's dependence materiality assessment. Using sector research and expert interviews, ENCORE's materiality assessment translates into a rating ranging from very low to very high reflecting how a disruption in the ecosystem service provision could materially affect business performance and be reflected in financial losses (see Figure 2 for an illustrative example).[12]

Based on the sectoral credit outstanding of Brazilian banks, the materiality of potential dependencies and impacts of ecosystem services provide a preliminary estimation of banks' physical risk exposure to biodiversity loss. We show the total amount of credit that, as of March 2021, is exposed to each ecosystem service by dependency materiality rating. For example, consider a company dependent on two ecosystem services (e.g., flood protection and disease control). Each Brazilian real this firm borrowed would count as one when measuring the exposure to each service. This metric provides a full account of the financial system exposure to each individual ecosystem service, though business processes are often dependent on multiple ecosystem services hence the former should be analyzed individually and cannot be added.

A second metric is calculated by accounting only for ecosystem services with high or very high dependencies to address the additionality issue. Assume that a company that borrowed one real is dependent on three ecosystem services, two of which have a high materiality rating while the third has a medium materiality. Then, the real borrowed will be equally distributed to the two ecosystem services with high materiality. This method would allow gauging the banks' overall

[10] The complete list of business processes and ecosystem services is available at: https://encore.naturalcapital.finance/en/data-and-methodology/services.

[11] DNB (2020) linked ENCORE's production processes (grounded in GICS) with the NACE Rev 2. We used this as a starting point to facilitate the linkage with the Brazilian economic sector classification standard, CNAE 2.0. The linkage is not univocal, as several business processes could be assigned to individual sectors or vice versa. Therefore, blending diverse business processes into one sector required assumptions of how these processes are used within the economic sector.

[12] The ENCORE dependencies on ecosystem services data is grounded on literature reviews carried out for each ecosystem service class and production process combination using Web of Science, Google and key document searches (e.g.: TEEB for Business, leading companies in the sector and industry initiatives). Expert interviews were conducted with sector specialists to validate information or to address data gaps for some sectors or production processes. See https://encore.naturalcapital.finance/en/data-and-methodology/methodology.

exposure to one or more ecosystem services, at the risk of underestimating the exposure of firms dependent on ecosystem services with lower materiality ratings. In addition, we break down this exposure by source of funding (earmarked vs. non-earmarked), banks' size,[13] borrowers' size, and loan quality.

Overall, our physical risk assessment should be considered as a lower bound as it only considers the first-order dependencies of an economic sector on ecosystem services. As noted by DNB (2020), in the ENCORE database a production process such as the cultivation of crops is directly dependent on animal pollination. Nonetheless, the processing of foods, a secondary industry, depends indirectly on animal pollination but this is not captured by the database.

Biodiversity loss and banks' loan quality

Loss of ecosystem services potentially impacts banks' balance sheets. To provide an illustrative exercise of these effects, we leverage the existing literature. We first obtain trend estimates in ecosystem services and economic indicators through 2030 under a scenario of ecosystem collapse, that is, a scenario where pressure on ecosystems pushes them to tipping points, resulting in a collapse in the provision of ecosystem services. Next, the variation on banks' NPLs associated with the macroeconomic conditions following such a collapse in ecosystem services is determined.[14]

By incorporating select ecosystem services into a computable general equilibrium model, a novel World Bank study attempts to quantify the nexus between economies and nature (World Bank, 2021). The study provides country-specific estimates of the decline in GDP growth through 2030 (using 2021 as baseline) due to a collapse in a selection of four ecosystem services: pollination of crops by wild pollinators, climate regulation from carbon storage and sequestration, provision of food from marine fisheries, and provision of timber. The ecosystem services collapse is benchmarked to a business-as-usual scenario where no ecological tipping points are reached.[15] Limitations, including un-exhaustive incorporation of feedback loops, and the consideration of a limited number of ecosystem services, suggest that this exercise only provides conservative estimates of the economic implications of collapsing ecosystem services.

[13] We follow the BCB classification of banks' size. Particularly, large banks are those with a total exposure to GDP ratio greater than 10 percent or those with foreign assets greater than US$ 10 billion.

[14] Due to the lack of data on loss given default, we are only able to consider information on frequency/probability of default and unable to extend to an expected loss framework.

[15]The World Bank ecosystem-economy modeling combines a general equilibrium model with a set of ecosystem service models that cover pollination, timber provision, fisheries, and carbon sequestration, whose interactions with the economy are projected to the year 2030. For that purpose, the model relies on three building blocks: (i) a general equilibrium economic model (CGE) that allows modeling of land-use change and incorporate the notion that sectors only compete for land that is suitable for their use; (ii) a set of spatially-explicit ecosystem service models to reflect the fact that the economy is embedded in the biosphere; and (iii) a simulator that allows converting outputs from the economic model into spatially explicit variables that serve as inputs to the ecosystem models. The model sequentially runs each of the building blocks.

Financial stability shocks tend to be more severe if shocks are abrupt and unexpected, while gradual losses allow banks to better manage and adjust their portfolios. Nonetheless, the World Bank study does not provide the economic impact distribution across the projection period, a key input for estimating the potential impact on the banking sector. To deal with this limitation, we undertook two exercises. In a first scenario, we assumed that the full impact on GDP growth of a collapse in ecosystem services occurs by the end of the projection period. In a second exercise, we assumed that half of the impact occurs by the end of the projection period. These exercises rely on an assumption of abrupt ecosystem shifts on the back of biodiversity degradation. These assumptions are in line with Lovejoy and Nobre (2018), who point out that a loss of just 20-25 percent of the remaining biome in the Amazon basin could trigger an ecosystem regime shift.[16]

The link with the banking sector is made through the historical relationship between banks' loan quality and GDP growth. Borrowers' repayment capacity tends to deteriorate under weaker macroeconomic conditions. Empirical evidence documents a negative relationship between bank NPLs and GDP growth (see, for example, Balgova, Plekhanov and Skrzypinska 2017; Ghosh 2015; and Beck and Jakubik 2013). For Brazil, GDP growth also stands out as a relevant driver of NPLs, as documented, among others, by Vazquez, Tabak, and Souto (2012) and Chang and others (2008). Based on historical sensitivity of NPLs to GDP growth in Brazil, we provide indicative estimations on the variation in NPLs associated with drops in GDP as a result of a collapse in ecosystem services. Given the limited knowledge on all potential channels that could lead to an impact on the banking sector, our estimate should be considered conservative.

Transition risks

Activities in biodiversity hotspots

Banks run transition risks when they provide financing to companies that are prone to require a costly adjustment towards a more sustainable economy. One clear example of such firms is presented by those that operate in protected or valuable areas. According to Dasgupta (2021), much of global biodiversity lies outside current protected areas. The materialization of these risks would entail the government designating new areas as protected areas and/or tightening environmental regulations, which would force firms operating in the area to adapt or even relocate, imposing costs to the companies involved. Therefore, the starting point of this analysis relies on the identification of areas that are currently protected. Then we identify valuable areas that could become protected in the near future based, among others, on their biodiversity richness. Third, we estimate the banks' loan allocation for all Brazilian formal firms and their establishments, also factoring in geographic information. As a final step, we summarize all the information obtained to estimate potential loan allocation in biodiversity hotspots at the municipality level.

[16] According to current WWF estimates, around 17 percent of the Amazon forest has been lost in the last 50 years. See https://www.worldwildlife.org/threats/deforestation-and-forest-degradation.

To identify protected areas, we used the World Database of Protected Areas (UNEP-WCMC and IUCN 2019). Our definition of protected areas encompasses all six categories of the International Union for Conservation of Nature (IUCN 2016).[17] We acknowledge that not all activities financed with bank loans are or could be prohibited in protected areas. For instance, protected areas cataloged under IUCN VI (protected areas with sustainable use of natural resources) are designated for low-level non-industrial use of natural resources compatible with nature conservation. Nonetheless, we decided to account for these areas as protected. Because of their conserved ecosystems and habitats, they could potentially "transition" to higher stringency levels of protection in the future.

To detect areas that could become protected in the coming years, we leverage the Systematic Conservation Planning (SPC), an initiative of the Brazilian government launched in the early 2000s and led by the Ministry of Environment.[18] The SPC collects and processes spatial information about species abundance, biodiversity hotspots, costs, and conservation opportunities. This information is complemented and validated through a series of participatory workshops with specialists and representatives from different sectors. This process occurs every five years and results in mapping areas of priority actions for biodiversity conservation in all major biomes and coastal and marine zones.[19] Actions are classified as extremely high, very high, and high.

We use spatial methods to determine priority areas that do not overlap with existing protected areas and their location in the Brazilian political-administrative divisions. Our methodology to undertake this identification closely follows Fonseca and Venticinque (2018). We first estimate biodiversity conservation gaps in Brazil as the most stringent priority areas currently not protected. In other words, these are areas with extremely high priority actions for biodiversity conservation that exclude existing protected areas. In addition, priority areas tagged as very high and high that do not overlap with protected areas are also identified. The size of these areas and their location are presented in Figure 3, along with federal unit lines. The drawing of political-administrative divisions was possible by blending the spatial information obtained in previous steps with information from the Brazilian Institute of Geography and Statistics (IBGE 2019).

We estimate firms' indebtedness and geographic location by combining granular information of credit outstanding by federal unit and economic sector, with detailed non-financial information of all formal Brazilian firms. On the one hand, our credit outstanding data (as of March 2021) provides a disaggregation of the 27 Brazilian federal units and more than 1,300 subclasses categorized according to the Brazilian National Classification of Economic Activities (CNAE 2.0). On the other hand, the latest census of the Brazilian formal labor market, *Relação Anual de Informações Sociais* (RAIS 2019), provides information on 3.9 million corporate establishments

[17] IUCN categories are: (Ia) Strict Nature Reserve, (Ib) Wilderness Area, (II) National Park, (III) Natural Monument or Feature, (IV) Habitat/Species Management Area, (V) Protected Landscape/ Seascape, and (VI) Protected area with sustainable use of natural resources.

[18] For a discussion of the SCP, see Fonseca and Venticinque (2018), Sarkar and Illoldi-Rangel (2010), and Margules and Pressey (2000).

[19] See http://areasprioritarias.mma.gov.br/2-atualizacao-das-areas-prioritarias.

located in the 5,659 Brazilian municipalities.[20] RAIS firms' characterization includes their economic activity (CNAE 2.0), and the municipality where the firms operate. Since both data sets identify administrative divisions and use the same classification for tagging firms' economic sectors, we could combine them. We assume that establishments with similar size within the same economic sector and administrative division exhibit similar bank indebtedness. Therefore, we distributed the credit outstanding within federal units and economic sectors according to the establishments' sectoral share of active employees.[21]

Finally, we summarize geographic and financial information at the municipality level. Our binding restriction to undertake a geographic-location-specific analysis is the availability of comprehensive georeferenced information on firms (and establishments) across the Brazilian territory and their credit outstanding with the banking sector.[22] Therefore, by aggregating the establishments' credit outstanding, we can estimate the amount of loans that banks allocate to each municipality. Next, we weigh the municipalities' loan allocation by the proportion of municipalities' surface covered by protected areas, and priority areas that do not overlap with protected areas. This provides us with an estimation of the banks' exposure to transition risks through corporations that might already be operating in protected areas or in biodiverse areas that could become protected in the coming years. For instance, assume that 5 percent of the municipality "A" surface is covered by protected areas, and that banks have an outstanding credit portfolio of BRL 100 allocated in the municipality "A." Then, Brazilian banks' credit exposure to transition risks in municipality "A" is BRL 5.

Having municipalities as our unit of the analysis entails unavoidable caveats as municipalities' size varies considerably across the country. For instance, the municipality of Altamira (Pará) is the largest in Brazil, with 159,533 square kilometers or 45 thousand times larger than the smaller one, Santa Cruz de Minas (Minas Gerais). The larger the municipality, the larger the probability of our estimation error.

Environmental controversies

Banks face reputational risks when they finance projects that have a negative impact on the environment, especially when the latter are involved in public controversies such as oil spillages or extensive deforestation. The reputational impact is assumed to be greater when the firms are found to have inadequate systems to manage the environmental footprint of their operations. This risk is being increasingly recognized by banks and financial institutions, as information about high-profile environmental degradation becomes part of the investment decision making of

[20] The 2019 RAIS contains a universe of 7.9 million facilities. We excluded from our sample financial sector facilities and those that did not have employees or kept their activities idle during 2019. After data cleaning, we ended up with 3.9 million establishments, employing a total of 46.5 million active employees.

[21] In other words: $Loan_{isf} = Loan_{sf} * \left(\frac{Employees_{isf}}{\sum_{i=1}^{N_{sf}} Employees_{isf}} \right)$, where $Loan_{isf}$ denote the credit outstanding of the establishment i that operates in the sector s and federal unit f.

[22] Studies such as DNB (2020) or others related to climate-related risks (e.g., NGFS 2020a) use data from Four Twenty Seven to identify business locations. However, its coverage for Brazil is significantly limited.

global investors. Large Brazilian firms have faced pressure from investors as well as banks to address deforestation risks and present action plans. For example, the largest meat processing company in the country recently faced the exclusion of its shares from a large asset manager's funds, as well as warnings by banks against investing in the company due to Amazon deforestation concerns.[23,24]

In line with DNB (2020), the credit provided to firms involved in environmental controversies is our proxy for banks' reputational risks. The MSCI ESG Database keeps a record of the controversies of listed companies and assesses the severity of their impacts on the environment by a combination of the scale of the impacts (how widespread it was) and their nature (from minimal to egregious).[25] MSCI defines controversies as single events or ongoing situations where company operations or products allegedly have a negative environmental impact. The database takes into consideration the fact that the impact of some events is indirect or difficult to determine hence having a lesser impact on the final score. In contrast, other events can affect a particularly vulnerable ecosystem, or evidence is found that the company knowingly acted in disregard of the law or the environment, thus exacerbating the relevance of the negative controversy. After the enterprises with environmental controversies have been identified, the information in their annual reports allows us to determine the volume of loans that these companies have received from Brazilian banks.

3. Estimating financial risks of biodiversity loss

Physical risks

Loss of ecosystem services

Brazilian banks lend BRL 811 billion to firms whose business processes are highly or very highly dependent on one or more ecosystem services. This amount represents 46 percent of the corporate credit portfolio and 20 percent of the total credit portfolio (Figure 4). In other words, 46 percent of the loans that banks allocate to corporates are subject to potential financial losses due to a disruption of ecosystem services. By analyzing separately this aggregate estimate by the source of resources (earmarked vs. non-earmarked), size of banks, borrowers' size, and loan quality, we find evidence of heterogeneity in the exposures to physical risks.

Earmarked credit is marginally more exposed to the risk of biodiversity loss. The Brazilian credit market is historically characterized by heavy government interventions for allocative purposes. Earmarked resources are credit granted by financial institutions with implicit or explicit subsidies

[23] See https://www.reuters.com/article/us-brazil-jbs-nordea/nordea-drops-jbs-shares-over-environment-covid-19-response-idUSKBN24X3VD

[24] See https://www.theguardian.com/environment/2020/aug/12/hsbc-sounds-alarm-over-investment-in-meat-giant-jbs-due-to-deforestation-inaction

[25] We acknowledge that we might be incurring a significant underestimation given that we only account for listed companies. Nonetheless, to the best of our knowledge, the MSCI ESG database has the most comprehensive coverage of firms' environmental controversies in Brazil.

from the government.[26] As of March 2021, earmarked resources represented 38 percent of total credit to non-financial corporates. The relative risk exposure of this type of credit compared to non-earmarked credit is slightly different. Whereas 45 percent of the non-earmarked credit is to firms with business processes highly or very highly dependent on one or more ecosystem services, this figure is 3.5 percentage points higher in the case of earmarked resources (Figure 5). This finding could have important implications for the design of subsidized credit schemes.

Credit granted by smaller banks and bank credit to small and medium enterprises (SMEs) is – proportionally – more susceptible to potential financial losses due to a disruption of ecosystem services. In detail, 49.8 percent of the credit provided by smaller banks to non-financial corporates is to those with business processes highly or very highly dependent on one or more ecosystem services, a figure that is 6.5 percentage points higher than in the case of large banks. In addition, 48.6 (43.9) percent of bank credit to SMEs (large corporates) is granted to those with business processes that are highly or very highly dependent on one or more ecosystem services.

Credit granted to firms with business processes highly or very highly dependent on one or more ecosystem services already present signs of stress. Notably, we find that banks' NPL portfolio exhibits a higher share of loans tilted to business processes vulnerable to ecosystem services disruption (47.8 percent) in comparison to their performing portfolio (45.9 percent). In the event of biodiversity degradation, the effects on the banking sector may be more significant if ex-ante firms are financially stressed.

The number of ecosystem services supporting specific production processes varies considerably. Processes such as large and small-scale irrigated arable crops are the ones that depend highly or very highly on a larger number of ecosystem services with 13 and 12, respectively. On the flip side, processes such as railway transportation rely critically on one ecosystem service only, that is, mass stabilization erosion control.

In terms of dependency on specific ecosystem services, we find that economic sectors to which Brazilian banks lent money are sizably dependent on ecosystem services that provide climate regulation, surface water, and groundwater. In detail, of every real that banks lend to corporates, 23, 20, and 17 cents, respectively, are either highly or very highly dependent on those ecosystem services (Figure 6). Among them, surface water is the ecosystem service with a higher share of very high dependence materiality. In terms of the economic sectors linked to more substantially exposed ecosystem services, the most exposed are utilities, manufacture of food products, and building construction (Figure 7). These sectors together represent 18 percent of the total credit portfolio to non-financial corporates.

Loss of flood and storm protection, mass stabilization and erosion control, and water flow maintenance also present relevant physical risks. Brazilian banks allocate 8 percent of their corporate credit portfolio to economic sectors highly or very highly dependent on ecosystem services that provide flood and storm protection. Accounting for medium materiality ratings, this

[26] For a discussion of earmarked credit in Brazil, see, for example, Byskov (2019).

ecosystem service presents the highest dependency across all services assessed, at 59 percent (Figure 6). Following in relevance, of every real that banks lend to corporates, 6 and 5 cents are either highly or very highly dependent on mass stabilization and erosion control, and water flow maintenance.

Biodiversity loss and banks' loan quality

Under a business-as-usual scenario, Brazil is projected to lose 6.5 million hectares of natural land between 2021 and 2030, the highest for a single country (World Bank, 2021).[27] Conversion to pastureland and cropland drives land use changes in Brazil. This loss of natural land-use causes detrimental impacts on the availability of ecosystem services (i.e., pollination, provision of timber, marine fisheries, and carbon sequestration), significantly affecting economic growth prospects. At the global level, real GDP could decline by US$ 90 billion by 2030, which could increase to US$ 225 billion if climate change damages linked to the loss of ecosystems are factored in.[28]

Comparing the business-as-usual scenario with a scenario where key ecosystem services collapse, global real GDP growth from 2021 to 2030 could decrease by US$ 2.7 trillion (-2.4 percent). This is equivalent to a decline in global real GDP growth by 10 percent. Brazil is one of the countries with the largest projected decline in monetary terms at US$ 150 billion, equivalent to 20 percent lower GDP growth (or 5.5 percentage points) from 2021 to 2030 (Figure 8 and Figure 9). World Bank (2021) further highlights the adverse effect on Brazil's oilseeds sector of pollination loss from ecosystem collapse, where its productivity would fall by 6 percent.

Macroeconomic conditions strongly influence the loan quality of banks in Brazil. Using dynamic panel econometric techniques covering the operations of 78 Brazilian banks, Vazquez, Tabak, and Souto (2012) show that a 2-percentage point drop in yearly GDP growth is associated with a long-term increase in NPLs of 3.3 percentage points. This parameter was estimated based on quarterly data between 2003q1 and 2009q1 and focused on lending granted with non-earmarked resources. The average NPL ratio during the authors' 7-year window period (3.6 percent) is broadly similar to what was observed before the COVID-19 pandemic (3.2 percent). Additionally, both periods exclude crisis episodes, reducing comparability issues of the parameter. This is particularly relevant, as NPLs are usually lower and less volatile during normal times than during banking crises (Ari and others 2019).

Based on those estimated coefficients, we estimate that under a low probability, high impact scenario where ecosystem services collapse, the banking system could experience a long-term increase in corporate NPLs in the order of 9 percentage points. This exercise assumes that the full impact on GDP growth occurs by the end of the projection period, that is, in 2030. Assuming a less abrupt impact of biodiversity loss on GDP growth, where half of the GDP growth drop

[27] This comparison covers 223 countries and territories, including Sub-Saharan Africa (44), Rest of South Asia (5), Rest of Southeast Asia (7), Central America (32), South America (11), Central Asia (21), Middle East and North Africa (17), Other Europe (4), Rest of East Asia (3), Oceania (24), and the EU (29).

[28] As indicated in the methodology section, these estimates are a lower bound.

occurs by 2029 (thus, banks are able to adjust their portfolios over time) and half is concentrated in 2030, the long-term increase on corporate loans could be 4.5 percent.

Our sensitivity analysis of banks' loan quality is preliminary and illustrative only, yet it provides an order of magnitude of the potential effects that a deterioration in ecosystem services can have on banks' balance sheets. Besides, this estimation is based on aggregated data, thus hiding heterogeneous effects at the sectoral level. Some sectors are expected to be considerably more affected than others in an economic activity contraction scenario. For instance, Vazquez, Tabak, and Souto (2012) show a higher sensitivity of changes in GDP for credit to agriculture, sugar and alcohol, livestock, and textile sectors. As a compounding effect, these sectors are also highly dependent on the provision of ecosystem services.

Transition risks

Activities in biodiversity hotspots

Globally, protected areas have increased significantly in recent years, and this trend is expected to continue as countries agree to more ambitious goals under the United Nations' auspices. The size of protected areas worldwide has almost doubled to 15 percent of land and inland waters worldwide since 1990 (UNEP-WCMC, IUCN and NGS 2018). In 2010, the Parties of the Convention on Biological Diversity (CBD), of which Brazil is a member, adopted the Strategic Plan for Biodiversity 2011–20 with the mission of halting biodiversity loss and enhance the benefits that biodiversity provides to people. Specifically, CBD established the Aichi Target 11, a commitment of protecting at least 17 percent of terrestrial and inland water areas by 2020. It is anticipated that in the October 2021 CBD meeting, member countries might decide to increase their commitments to protect land and inland waters up to 30 percent. Such an expansion based on ecological criteria would greatly impact the status of vast regions in Brazil.[29]

In Brazil, the total current protected area of land and inland waters is over 1.5 million square kilometers, approximately 18 percent of its surface. Brazil achieved the 2020 Aichi Target 11 well ahead of time; as of 2015, protected areas already covered 17.2percent (OECD 2015). Nowadays, all federal units have protected areas from 208 to over 500,000 square kilometers, representing about 1 percent to over 90 percent of each state's surface.[30] For instance, Sergipe is one of the states with a lower share of protected areas at 0.95 percent, mostly explained by Serra de Itabaiana National Park. In contrast, 90 percent of the Federal District and 64 percent of the Amazonian state of Amapá are protected (See Figure 3 and Panel A of Figure 10). In Amapá, almost half of the protected area is explained by one of the world's largest tropical forest national parks, the Tumucumaque Mountains National Park. In absolute terms, the states with the largest protected areas are Amazonas and Pará, with more than 500,000 and 400,000 square kilometers, respectively.

[29] The mere designation of protected area is not enough in terms of their role for conserving and restoring natural capital. According to Dasgupta (2021), only 20 percent of protected areas around the globe are being well managed.
[30] Throughout the paper, we consider the Federal District as a state for simplicity.

Priority areas for biodiversity conservation that do not overlap with currently protected areas cover 28 percent of the Brazilian territory. The Brazilian government pipeline for implementing measures for the conservation, recovery, and sustainable use of ecosystems includes Mato Grosso as the state with the larger surface of priority areas (40 percent). The states of Tocantins and Bahia also have a significant priority area share, at 36 and 34 percent, respectively. Nonetheless, our definition of conservation gaps, a more conservative measure that considers the more stringent priority area level (extremely high), depicts a different picture. Conservation gaps are more relevant in Espiritu Santo, Rio Grande do Sul, and Rio de Janeiro, at around 10 percent in the three states.

About one-third of banks' loan portfolio to corporates is allocated to firms in 10 municipalities out of the more than 5,600 country-wide (Figure 11). The Herfindahl-Hirschman Index (HHI), a quantitative measure of concentration in a certain market, shows a low concentration level at 233.[31] Aggregating at the state level, the concentration is still relatively low, with an HHI of 1,299. The geographical concentration of banks' loan portfolios in Brazil is the lowest in the Latin America and the Caribbean region (Calice and Miguel 2021). The Southeast region concentrates 51 percent of the banking system assets, being the states of São Paulo and Rio de Janeiro the most relevant, with 30 and 11 percent of the system's assets, respectively. In contrast, while the North Region is the most geographically extensive, encompassing 45 percent of the Brazilian territory, its 7 states receive 4 percent of the banking assets only.

We find that as of March 31, 2020, Brazilian banks had BRL 254 billion in credit exposure to establishments that could be operating in protected areas. This amount is equivalent to 15 percent of the corporates' credit portfolio. The exposure could increase to BRL 437 billion (25 percent of the corporates credit portfolio) should conservation gaps close, and to BRL 664 billion (38 percent of the corporates credit portfolio) should all priority areas become protected. Figure 10, Panel B, provides more details.

Environmental controversies

Brazilian firms for which environmental controversies have been recorded and balance sheet data is available held BRL 109 billion in financial debt with credit institutions as of December 31, 2019. Out of 143 Brazilian firms, environmental incidents were recorded for 11 of them. Firms involved in severe or very severe controversies had debt liabilities of BRL 65 billion, while firms with moderate controversies were exposed for BRL 44 billion.

A well-known example of a very severe environmental controversy was the flooding and widespread environmental damage due to the Fundao tailings dam collapse, which caused flooding and widespread environmental damage in the state of Minas Gerais in 2015. In an

[31] The HHI is calculated as a sum of the squared market shares (measured as a share of total corporate credit of the banking sector) of each bank in a market. An HHI of less than 1,500 typically identifies low concentration, an HHI between 1,500 to 2,500 identifies a moderately concentrated marketplace, while an HHI of above 2,500 suggests a highly concentrated marketplace.

agreement with the Brazilian authorities, the company agreed to pay at least BRL 20 billion for environmental, social, and economic damages over a 15-year period. More recently, the Brazilian government fined another company with BRL 24 million for allegedly sourcing cattle raised in illegally deforested land. This case is cataloged as severe in our analysis (see Table 2).

4. Concluding remarks

Biodiversity loss can have significant consequences for the economy and the financial sector in Brazil. The results presented in this paper, to the best of our knowledge, the first to attempt to quantify bank exposures to biodiversity loss in an emerging market, suggest that Brazilian banks have material exposures to risks resulting from biodiversity loss.

Brazilian banks lend to firms that are at least partly dependent on ecosystem services for the production of their goods and services. Loss and degradation of ecosystem services can lead to substantial disruption of business processes and financial losses. We find that, as of March 2021, Brazilian banks had an outstanding domestic credit exposure of BRL 811 billion to non-financial corporates that operate in sectors highly or very highly dependent on one or more ecosystem services. This accounted for 46 percent of the total corporate loan portfolio and 20 percent of the total credit portfolio, and is slightly tilted to firms that receive government-subsidized resources through financial institutions. By comparison, the total worldwide exposure to physical risks of Dutch financial institutions at the end of 2019 was 36 percent of their total portfolio (DNB 2020). The highest dependence of Brazilian firms is on the ecosystems that provide climate regulation, ground water and surface water. Based on historical sensitivity of Brazilian banks' credit quality to macroeconomic conditions (see Vazquez, Tabak, and Souto 2012) and macroeconomic modeling of ecosystem services (World Bank, 2021), we estimate that the GDP losses associated with the collapse in ecosystem services could translate into a cumulative long-term increase in corporate NPLs in the order of 9 percentage points, other things being equal.

Brazilian banks also lend to firms that can have an adverse impact on biodiversity because they operate in protected areas and priority areas for biodiversity conservation and/or are involved in environmentally controversial activities. The adoption of biodiversity-related regulation and policy, technological progress, shifts in market sentiment and preferences, litigation and reputational damage can generate losses for companies and ultimately for banks. We find that at end-March 2021 Brazilian banks had an outstanding loan exposure of BRL 254 billion or 15 percent of their corporate portfolio to firms potentially operating in protected areas. By comparison, Dutch banks' global exposure to firms operating in protected areas was 7 percent at end-2019 (DNB 2020). Brazilian banks' exposure to transition risks could increase to BRL 437 billion (25 percent of the corporate credit portfolio) should conservation gaps close, and to BRL 664 billion (38 percent of the portfolio) should all priority areas become protected. We also find that, as of December 31, 2019, Brazilian banks had an outstanding loan exposure of BRL 109 billion to the 11 of the 143 Brazilian listed firms for which environmental controversies have been recorded. By contrast, Dutch financial institutions' worldwide exposure to firms involved in incidents was € 96 billion at end-2019 (DNB 2020) or about BRL 608 billion at current exchange rates.

Our results, driven by available approaches and data, are subject to several important caveats. These suggest that our estimates err on the side of caution, presenting a lower bound and presumably underestimating full physical risk exposures. A first caveat relates to the limited knowledge of the interaction among ecosystems and between ecosystem services and the economy. This implies, among others, that it is difficult to gauge the materiality of the dependencies on ecosystem services of business processes and economic sectors and firms. For that we rely on existing studies and approaches, which only consider first-order dependencies. A second and related caveat is that we omit in our analysis the interaction between biodiversity loss and climate change, which are mutually reinforcing phenomena, with one compounding the other (IPBES 2019). This implies that Brazilian banks, which are already significantly exposed to climate-related physical and transition risks (Calice and Miguel 2021), may face the combined impacts arising from the interaction between biodiversity loss and climate change and natural disasters. Another caveat is that our analysis focuses only on domestic exposures of Brazilian banks through lending. Though these account for the bulk of their risk assets, Brazilian banks may be exposed to biodiversity loss through other forms of investment (i.e. equity investment). They can also be exposed to regional impacts of biodiversity loss through their international operations. Other financial institutions, namely insurance companies, pension funds and asset managers, may also have exposure to biodiversity loss through their investment portfolios. Further research can address these and other shortcomings, including by leveraging the work of the NGFS.

Despite their limitations, the results of this paper highlight the materiality of Brazilian banks' exposure to the risks of biodiversity loss. This has implications for both banks and BCB. Banks could begin taking steps to identify and measure their exposures to biodiversity loss with a view to ultimately monitor and mitigate any material risks arising from their lending and investment activities. Banks could also take steps to disclose the biodiversity impacts of their investments and require the same from firms in their portfolios. In that regard, the recently established Taskforce on Nature-related Financial Disclosures (TNFD) could offer the appropriate framework.[32] A few Brazilian financial institutions have already joined the Informal Working Group tasked with developing the scope and workplan of the TNFD, and more could join. Brazilian banks have been historically at the forefront of industry-led initiatives to foster sustainable finance and mitigate social and environmental risks. They could take the lead on the biodiversity front as well.

BCB, which in 2014 was among the first central banks to require supervised entities to measure social and environmental risks, recently added a sustainability dimension to its institutional strategy. BCB could explicitly add nature-related risks to its supervisory agenda. The sustainability pillar of its work program already includes initiatives that can have positive effects on conservation and restoration of biodiversity. For example, BCB plans to issue regulation for

[32] Building on the work of the Task Force on Climate-related Financial Disclosures, the TNFD was established in July 2020 by a group of international organizations and NGOs with the objective to provide a framework for financial institutions and corporates to assess, manage and report on their dependencies and impacts on nature. The TNFD is aiming to launch in 2021 and deliver a relevant reporting framework by 2023. See https://tnfd.info/.

mandatory disclosure of social, environmental, and climate risks by financial institutions.[33] BCB also plans to establish a Sustainable Rural Credit Bureau that would embed sustainability criteria defined both by statutory and non-statutory regulations.[34] These actions could be complemented by efforts aimed at better understanding the transmission channels through which biodiversity loss can translate into financial risks. In a natural extension of this paper, BCB could collect and analyze more granular firm-level data. In time, BCB could also design and implement nature-related stress tests, in line with the international guidance provided by the NGFS. The aim would be to assess how and to what extent biodiversity factors could be incorporated into relevant microprudential and macroprudential policy. For BCB to achieve the ultimate goal of engraining biodiversity considerations into the operations of the local financial system, it will need to involve key stakeholders such as the Ministry of Finance, the Ministry of Agriculture and the broad financial sector.

Better management of nature-related financial risks would not only contribute to the safety and soundness of individual banks and the financial system more broadly; it could also help reduce the flow of capital into economic activities that harm nature, thus reducing the need for funding to conserve and restore biodiversity and ecosystem services. Globally, the estimated biodiversity financing gap – the difference between the current flow of public and private funds toward biodiversity protection and the estimated annual funding needed to halt the decline in global biodiversity between now and 2030 – is on average US$ 711 billion per year (Deutz and others 2020). While new sources of funding are needed, including mechanisms that increase private capital flows into conservation (World Bank 2020), much of the funding may come from actions taken by financial institutions to understand and manage the risks to biodiversity from their investments. Given the significant amount of money lent by Brazilian banks to potentially damaging projects, the mainstreaming of biodiversity-related risk management practices in the banking sector presents an enormous opportunity to prevent negative impacts to biodiversity.

[33] BCB Public Consultation No. 86/2021 - Regulation on the disclosure of social, environmental, and climate-related risks by financial institutions. Available at https://www.bcb.gov.br/content/financialstability/ruralcreditdocs/BCB_Public_Consultation_86.pdf.

[34] The Sustainable Rural Credit Bureau will apply a second layer of automated verifications to check the environmental compliance of credit operations. The first verification layer, as defined by the *Conselho Monetário Nacional*, shall be done by the financial institutions.

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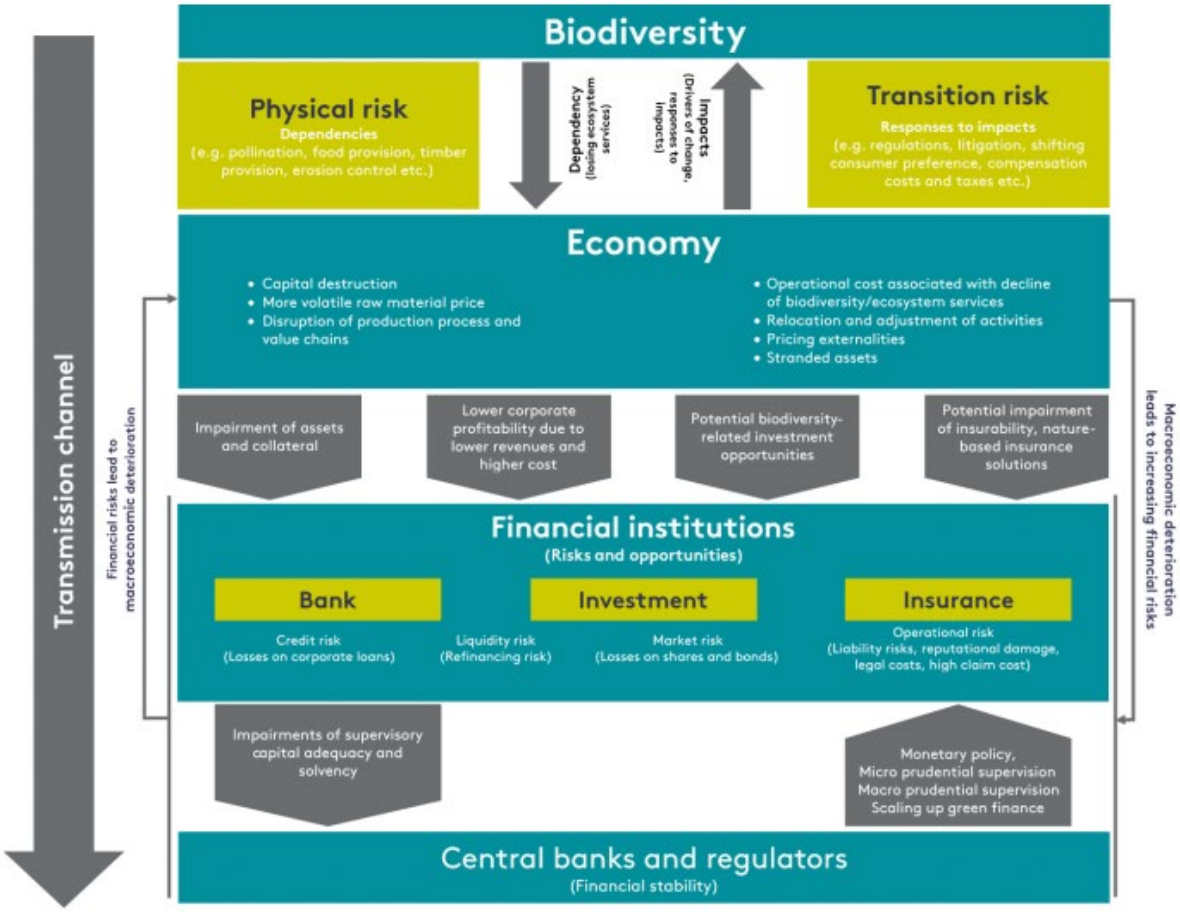
Appendix

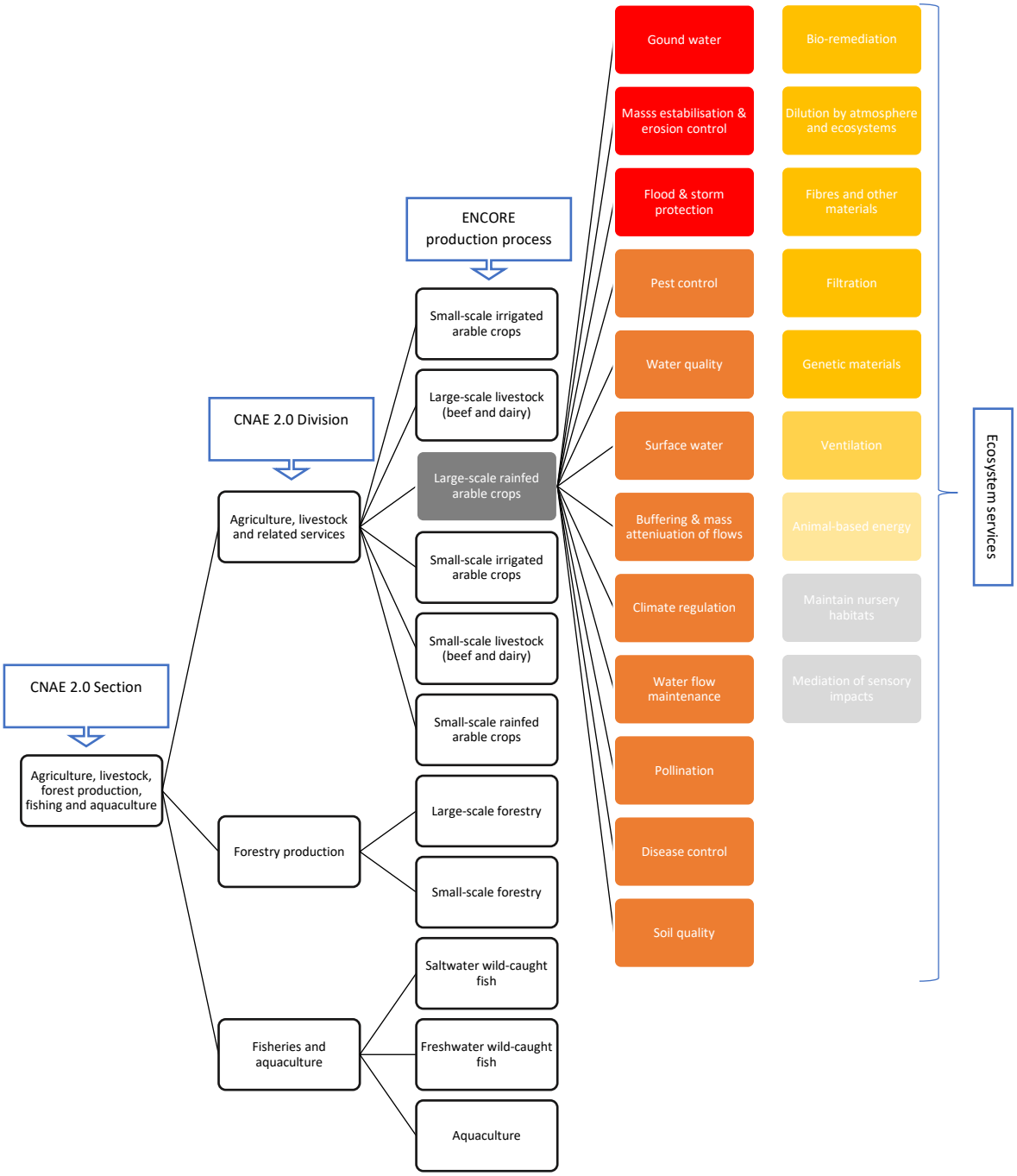
A. Figures

Figure 1: The Relationship Between Biodiversity and Financial Stability



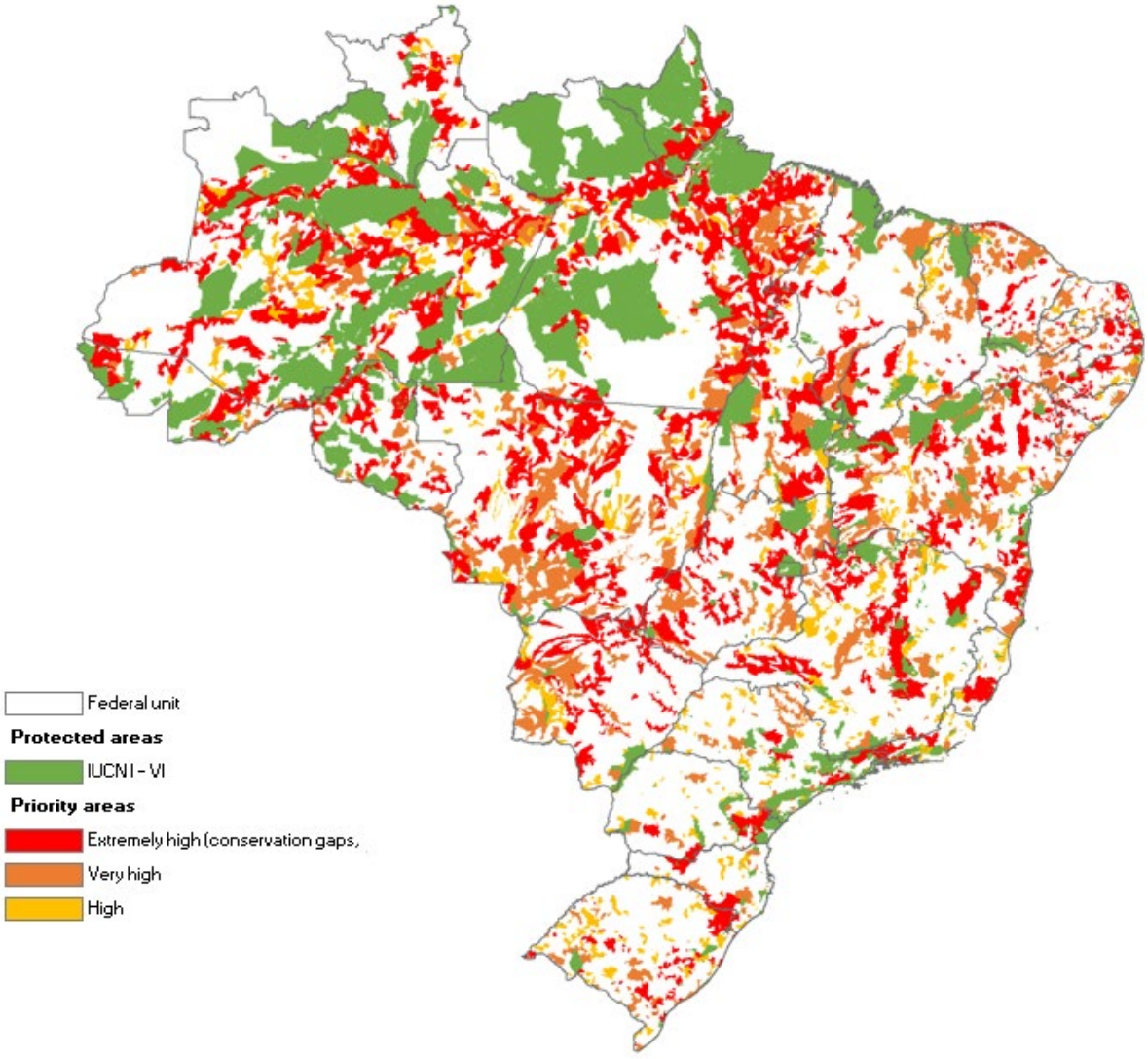
Source: NGFS INSPIRE

Figure 2 – Example of ENCORE Materiality of a Production Process Dependencies on Ecosystems, Large-scale irrigated arable crops



Source: own elaboration based on ENCORE, and BCB. **Note**: In red very high dependency, in orange high dependency, in yellow medium dependency (with lighter shades for low and very low), grey shows no dependency.

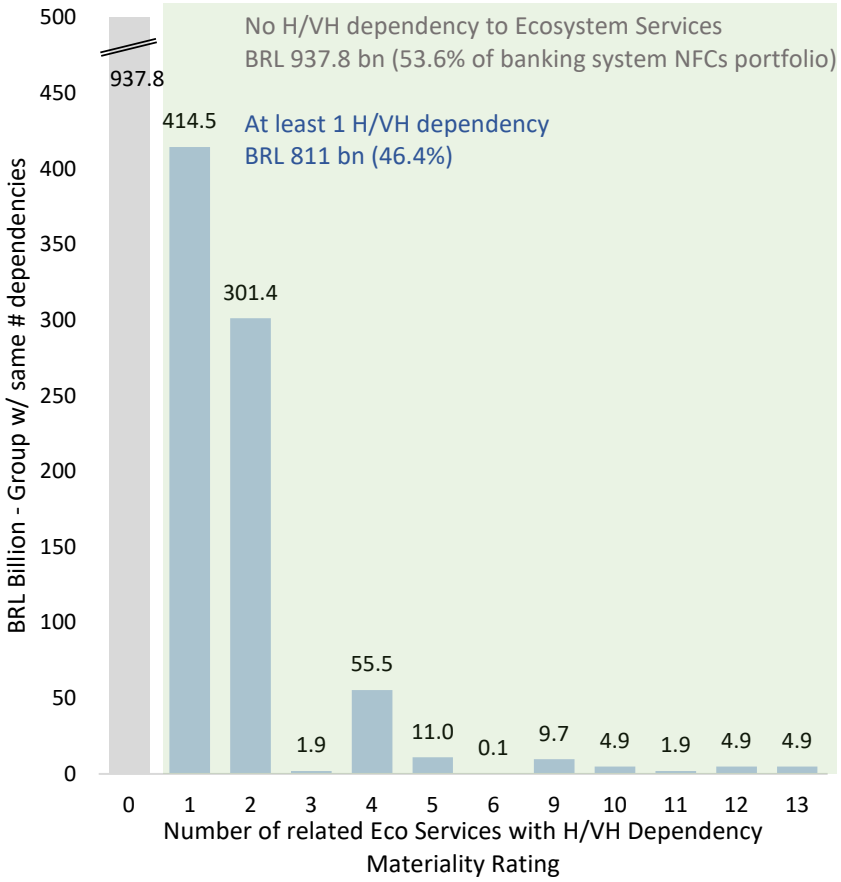
Figure 3 – Protected and Priority Areas



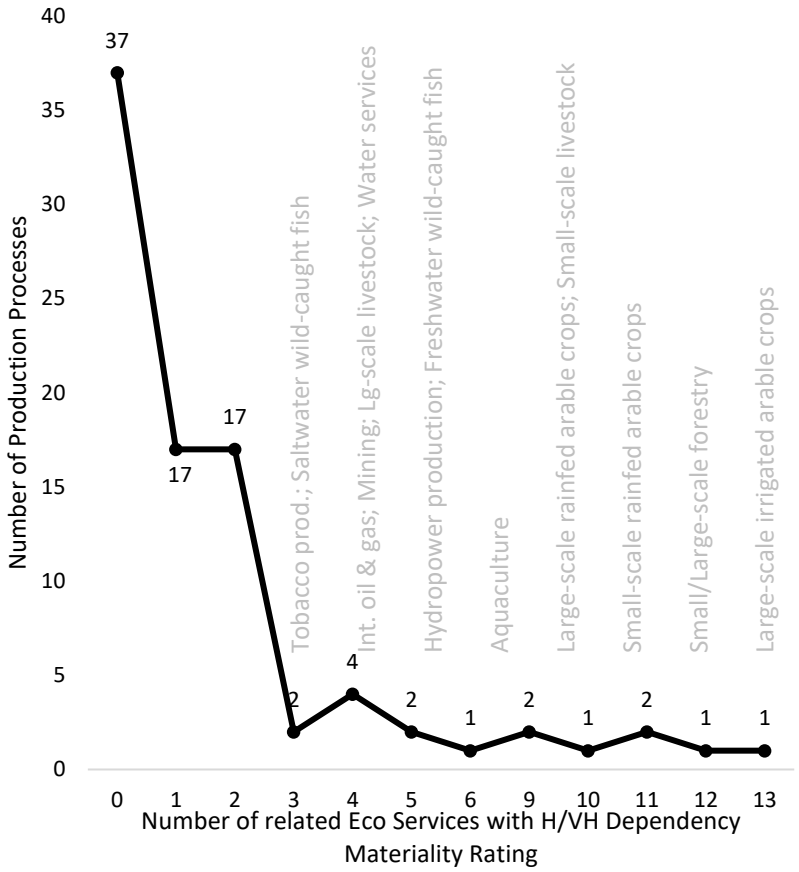
Source: own elaboration based on UNEP-WCMC & IUCN (2019) and MMA

Figure 4 - Processes with High/Very High Dependency Materiality

Panel A - Credit Exposure to Processes with High/Very High Dependency Materiality (in BRL million)

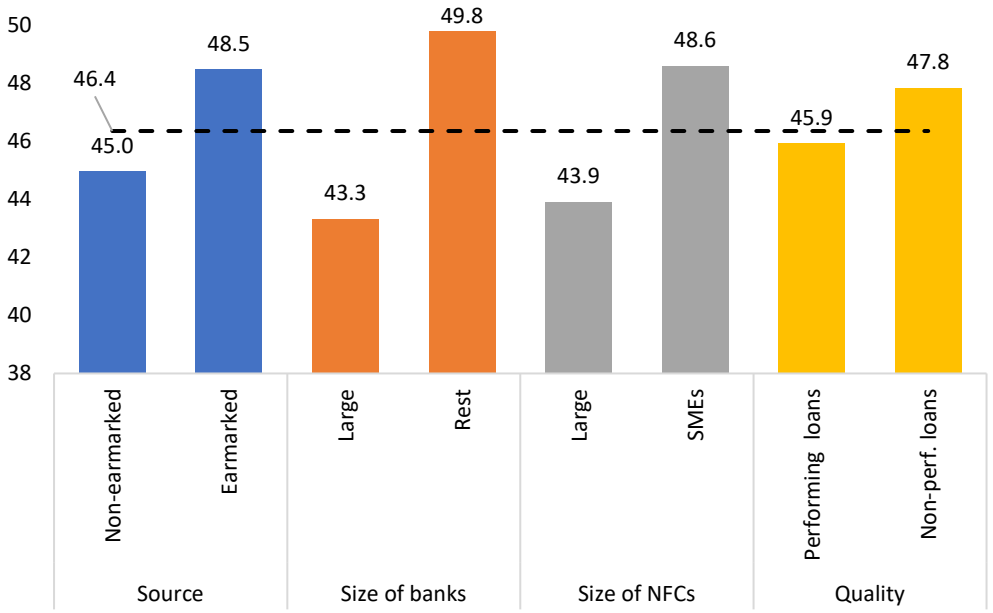


Panel B - Number of Production Processes with High/Very High Dependency Materiality (in number)



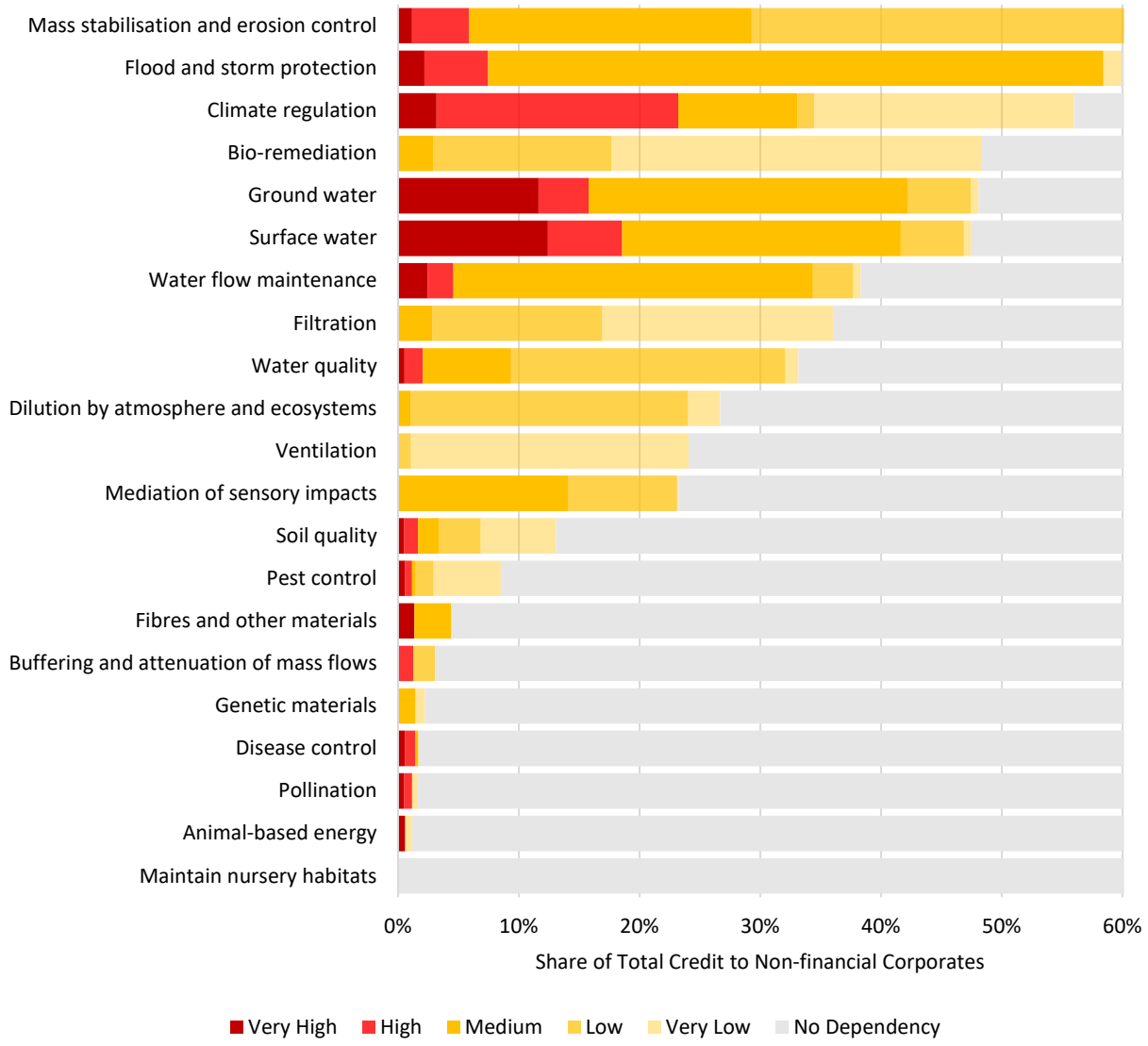
Source: own elaboration based on ENCORE and BCB.

Figure 5 - Credit Exposure to Processes with High/Very High Dependency Materiality



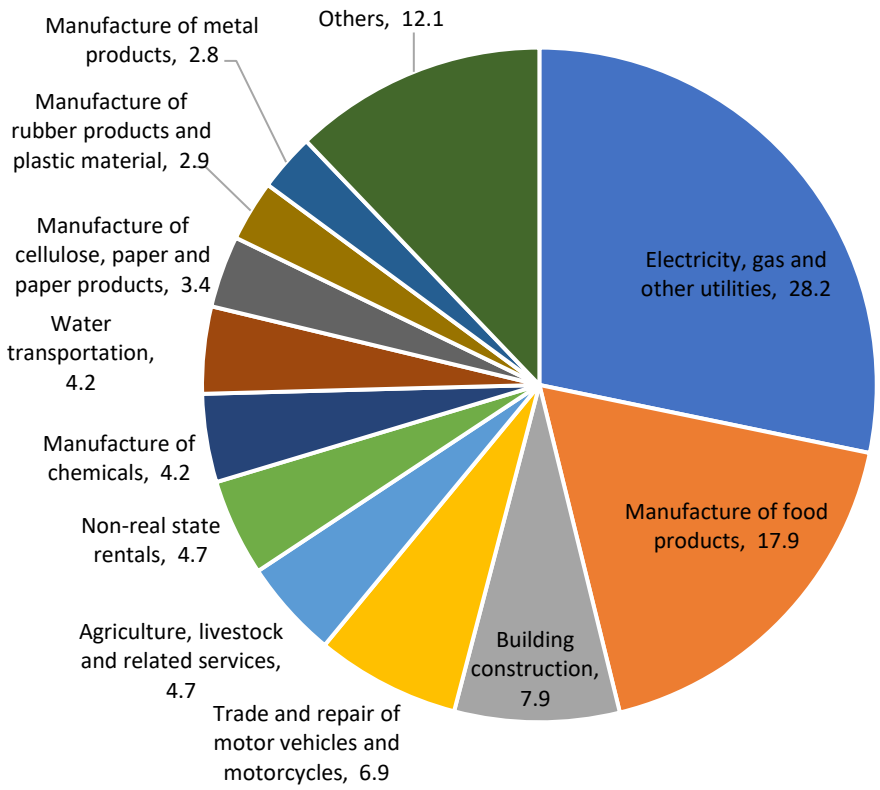
Source: own elaboration based on ENCORE and BCB. **Note**: The dashed horizontal line depicts the aggregated credit exposure to processes with high/very High dependency materiality rating (Figure 4a). Large banks correspond to BCB classification S1: Multiple banks, commercial banks, investment banks, exchange banks and savings banks that present a total exposure to GDP ratio greater than 10 percent or those with foreign assets greater than US$ 10 billion.

Figure 6 - Credit to Non-financial Corporates: Dependency of the Banking System Portfolio to Individual Ecosystem Services (in percentage)



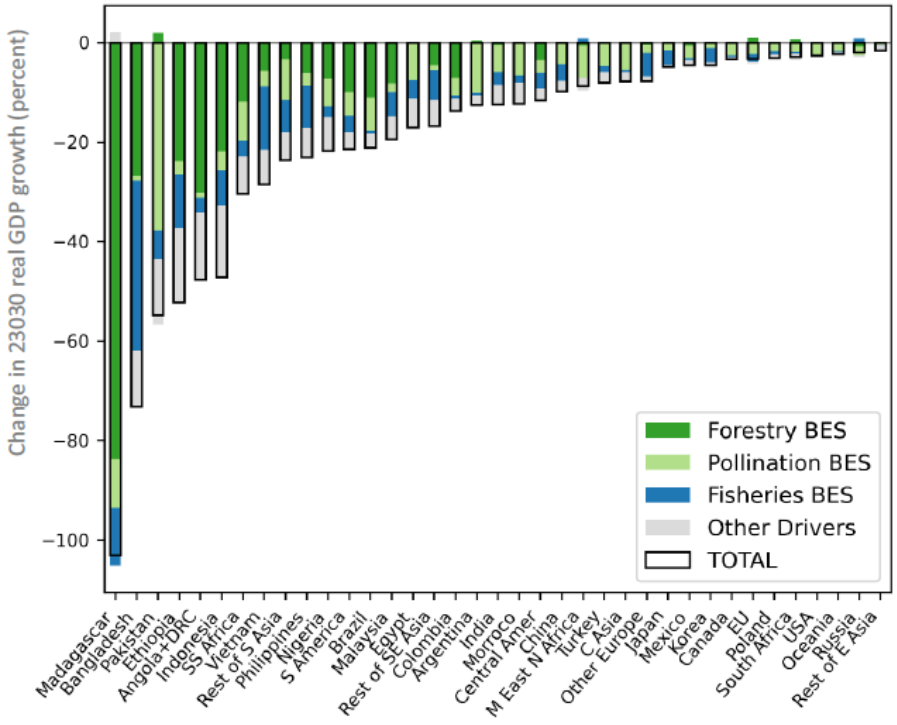
Source: own elaboration based on ENCORE and BCB.

Figure 7 – Economic Sectors Linked to More Substantially Exposed Ecosystem Services, March 2021



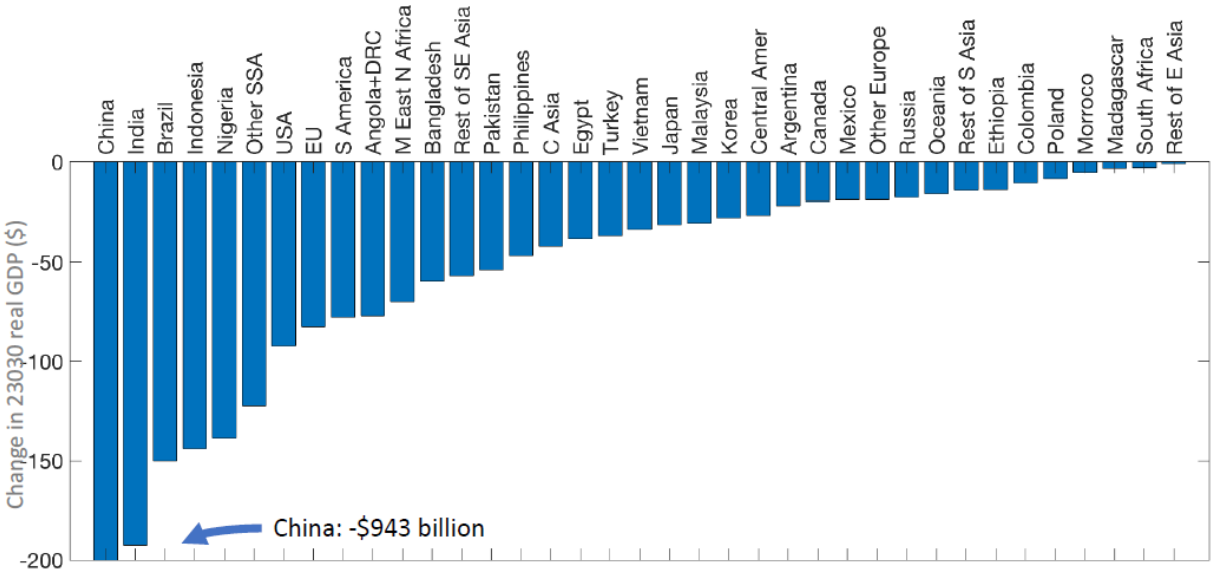
Source: own elaboration based on ENCORE and BCB.

Figure 8 - Change in Real GDP Growth, 2021-2030, Under Ecosystem Collapse Scenario Compared with Business-as-Usual Scenario



Source: World Bank, 2021.

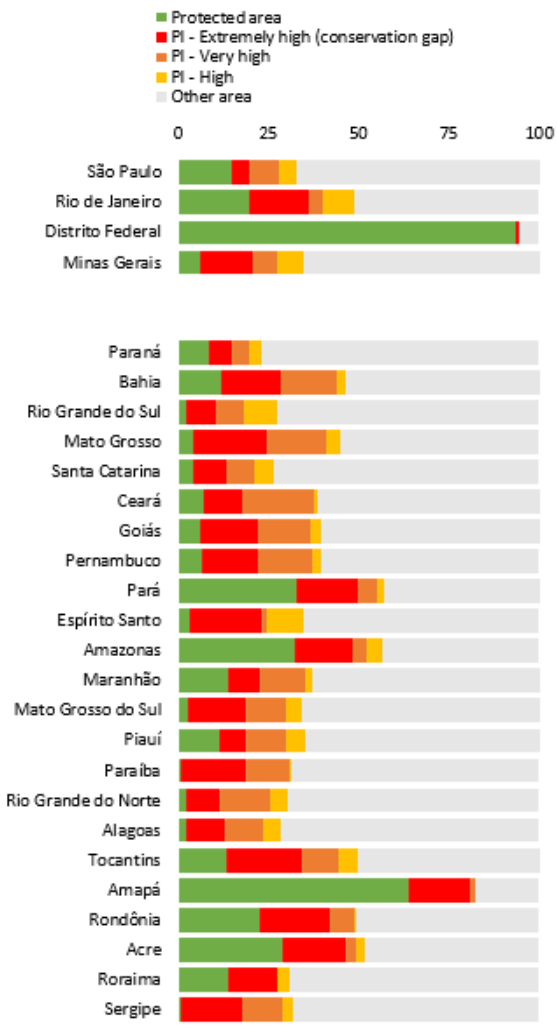
Figure 9 - Change in 2030 Real GDP Under Ecosystem Collapse Scenario Compared with No-Tipping-Point Scenario



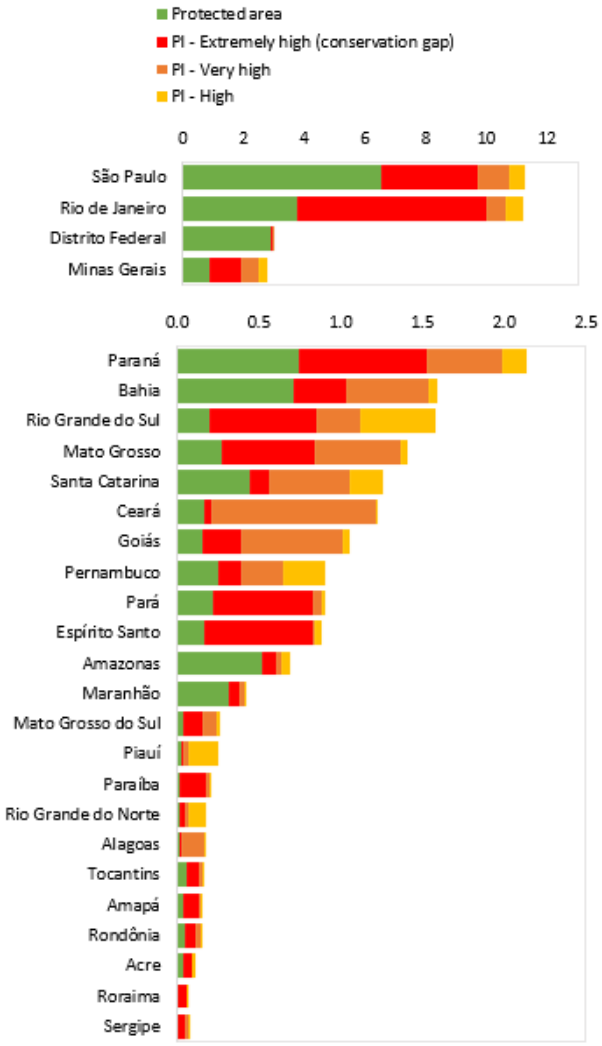
Source: World Bank, 2021.

Figure 10 – Transition risks estimates

Panel A - Share of Protected and Priority Areas by Federal Unit (in percentage)

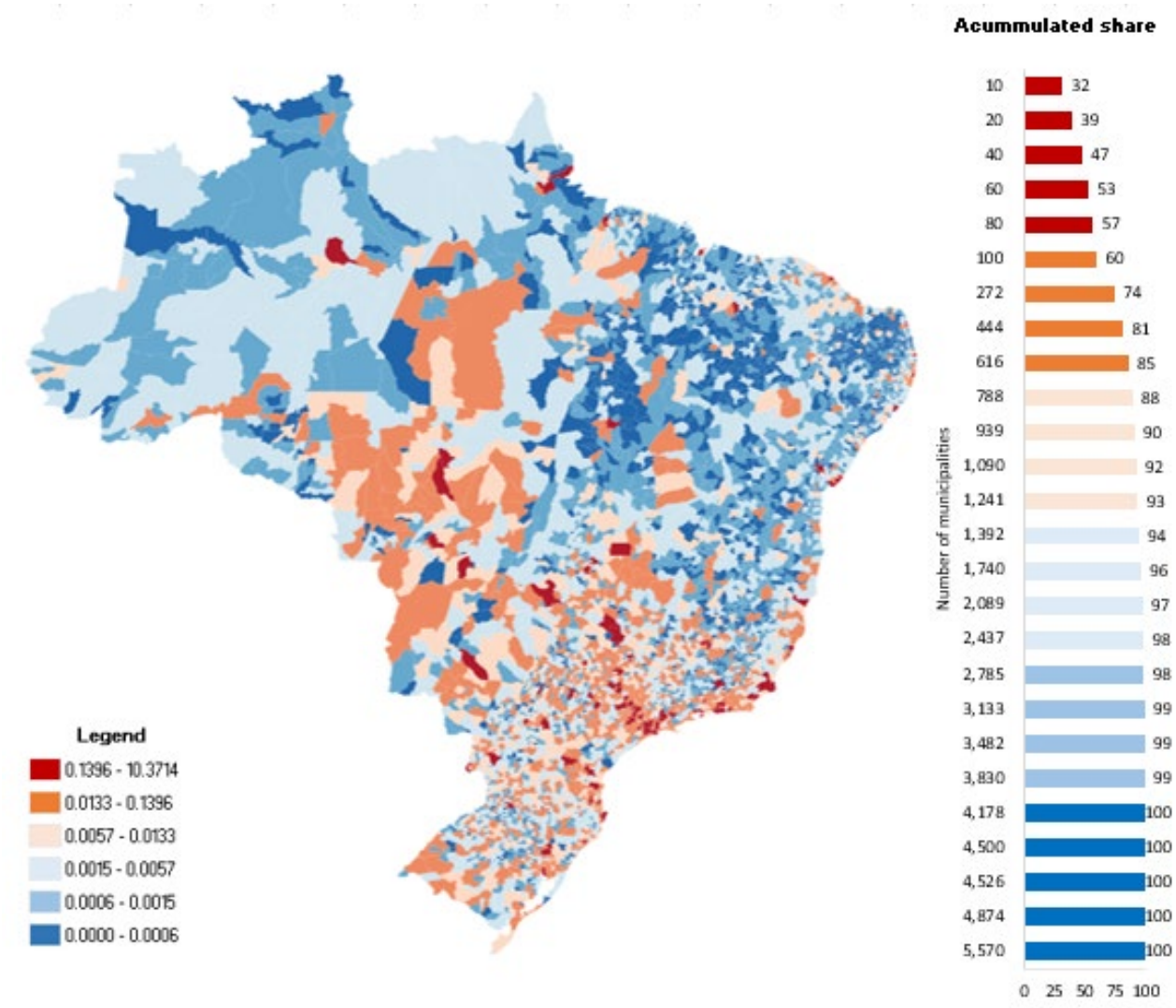


Panel B - Share of Banks' Non-Financial Corporates Credit Portfolio in Protected or Priority Areas by Federal Unit, March 2021 (in percentage)



Source: own elaboration. **Note:** Our identification is at the municipality level. For presentation purposes, we aggregate by federal unit.

Figure 11 - Banks' Credit Outstanding to Non-Financial Corporates, Distribution Across Municipalities, March 2021 (in percentage)



Source: own elaboration

Note: The distribution municipalities shares are a slight modification of the typical boxplot parameters. The six classes are defined as follows: [min, p25], (p25, p50], (p50, p75], (p75, p75 + 1.5*iqr], (p75 + 1.5*iqr, top 100], (top 100], where iqr is interquartile range.

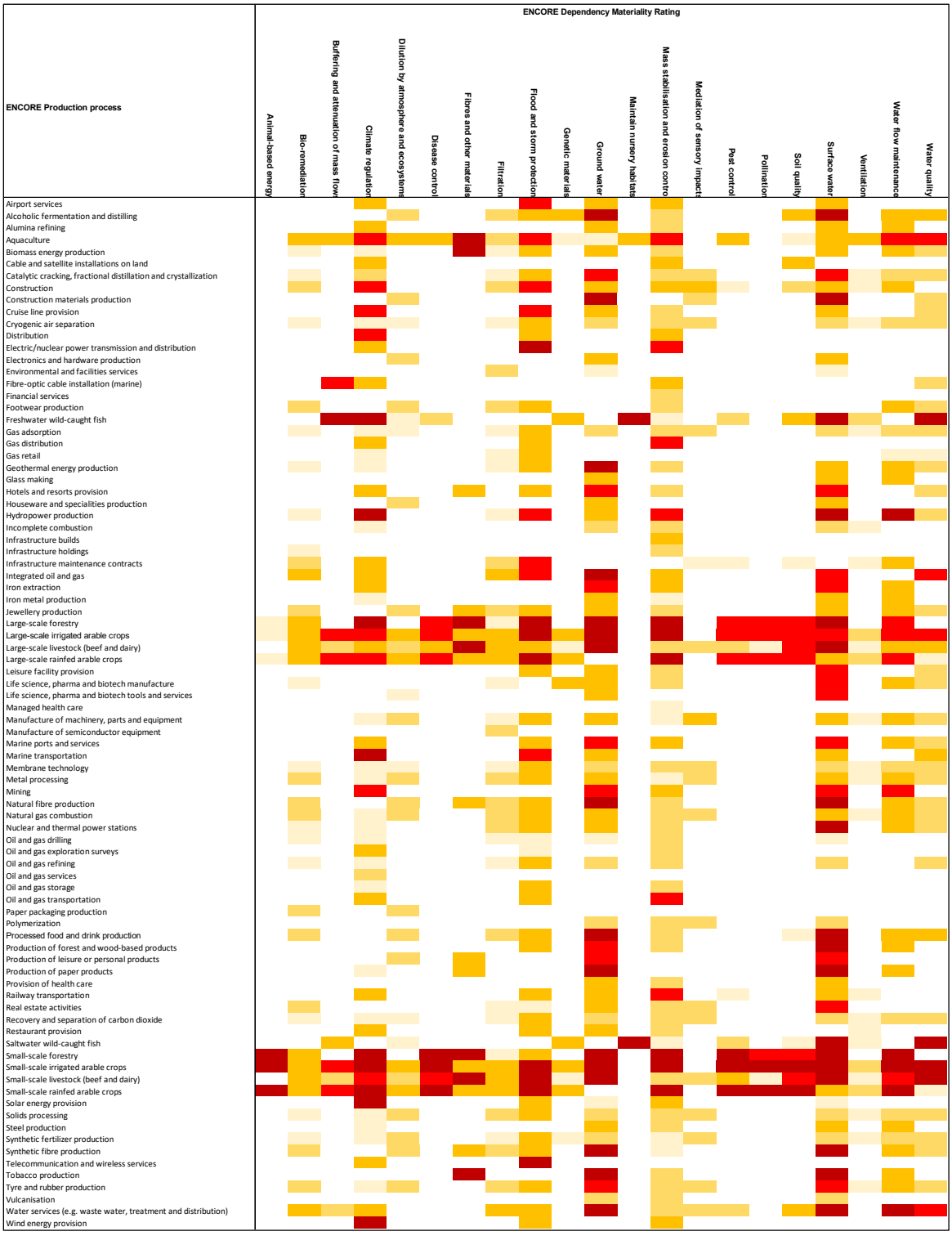
B. Tables

Table 1 - Data Sources

Risk type	Data	Source	Description
Physical risk	Credit outstanding	Banco Central do Brasil	End-of-period balance of credit operations outstanding in the Brazilian National Financial System, following the CNAE (*Classificação Nacional de Atividades Econômicas*) classification at the subclass level (7-digits). Data as of March 2021.
	Dependency Materiality Rating	ENCORE - Developed by Natural Capital Finance Alliance in cooperation with UNEP-WCMC; UNEP-WCMC and NCFA	Materiality of production processes' dependencies to biodiversity services. Classification standards are GICS (for production processes) and CICES (for ecosystem services).[35]
Transition risk	Credit outstanding	Banco Central do Brasil	End-of-period balance of credit operations outstanding in the Brazilian National Financial System, following the CNAE (*Classificação Nacional de Atividades Econômicas*) classification at the subclass level (7-digits). Data as of March 2021.
	Facilities geographical locations	*Relação Anual de Informações Sociais* (RAIS) - Brazilian Ministry of Economy	Matched employer-employee dataset assembled annually that provides the census of Brazilian formal labor market.[36]
	Protected areas	The World Database on Protected Areas (WDPA) - IUCN, UNEP-WCMC	Global database of marine and terrestrial protected areas.[37]
	Priority areas	Brazilian Ministry of Environment (MMA)	Mapping areas of priority actions for biodiversity conservation in all major biomes and in coastal and marine zones.
	Municipal mesh	Brazilian Institute of Geography and Statistics (IBGE)	Digital municipal mesh of the Brazilian political-administrative divisions[38]
	Environmental Controversies	MSCI - Environmental Controversy Database	MSCI environmental controversy score
	Firms' bank loans	Firms' annual reports	Consolidated as of December 2019.

[35] https://encore.naturalcapital.finance/en/data-and-methodology/data
[36] http://www.rais.gov.br/sitio/index.jsf
[37] https://www.protectedplanet.net/en/thematic-areas/wdpa?tab=WDPA
[38] https://www.ibge.gov.br/en/geosciences/territorial-organization/territorial-organization/18890-municipal-mesh.html?edicao=27766&t=sobre

Table 2 – ENCORE Production Process and Ecosystem Services Dependency Mapping



Source: ENCORE. **Note**: Colors indicate materiality rating: ● Very High, ● High, ● Medium, ● Low, and ● Very Low.

Table 2 – Example of Moderate, Severe, and Very Severe Environmental Controversies

Severity	Indicator	Scale of Impact	Nature of Harm	Type	Description
Very Severe	Toxic Emissions & Waste	Extremely Widespread	Serious	Structural	**Severe flooding and widespread environmental damage due to Fundao tailings dam collapse**. In November 2015, the Fundao tailings dam collapsed, causing severe flooding and widespread environmental damage in Minas Gerais state. The company operated the tailings dam, which had stored iron ore tailings from a company's mine. Mud, mine tailings and wastewater from the dam severely contaminated River Doce and its tributaries and traveled over 500 kilometers to the Atlantic Ocean. The company entered into an agreement with the government to pay at least BRL 20 billion for environmental, social, and economic damages, in a 15-year period.
Severe	Supply Chain Management	Extremely Widespread	Very Serious	Structural	**Penalty for alleged sourcing of cattle from illegally deforested land**. IBAMA, Brazil's environmental protection agency, ordered the company to pay a BRL 24 million penalty for allegedly sourcing cattle that were raised in illegally deforested land. The company was accused of knowingly buying 49,000 cattle from restricted areas and via 'laundering' transactions that aimed to conceal the cattle sources between 2013 and 2016. IBAMA claimed that of all the animals raised in deforested lands, 84percent were supplied to this company. In addition to the penalty, the agency suspended the operations of two packing plants along with 13 other facilities in the state of Para.
Moderate	Toxic Emissions & Waste	Limited	Serious	Structural	**Penalty and order to evacuate residents potentially exposed to carcinogenic waste in Rio de Janeiro State**. The company faced a BRL 35 million penalty and multiple lawsuits related to environmental contamination from its industrial waste disposal site in the city of Volta Redonda, Rio de Janeiro state. According to the state environmental regulator INEA, the company failed to disclose to residents that the area was contaminated with hazardous waste, including carcinogenic substances. The state's environmental prosecutor ordered the company to remove the waste and evacuate 750 families residing adjacent to the disposal site. INEA and the federal environmental prosecutor filed separate legal actions to compel the company to comply with the state environmental prosecutor's demands.

Note: Scale of the impact - The scale of impact, on a scale ranging from extremely widespread to low; Nature of harm - The nature of impact on a scale ranging from egregious to minimal harm; Type - Structural problems that could pose future material risks for the company. **Source**: Own elaboration based on MSCI.