Policy Research Working Paper 10432

Biodiversity and Finance

A Preliminary Assessment of Physical Risks for the Banking Sector in Emerging Markets

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WORLD BANK GROUP
Finance, Competitiveness and Innovation Global Practice
May 2023

Policy Research Working Paper 10432

Abstract

Economic activity depends on a flourishing biodiversity and intact environment through the provision of ecosystem services. The depletion of these services poses physical risks for the financial sector. This paper attempts to measure the potential exposure of the banking systems in 20 emerging markets to nature loss through their lending portfolio. The results show that banks in emerging markets allocate around half of their credit portfolio to firms whose business processes are highly or very highly dependent on one or more ecosystem services. The results also provide initial and preliminary evidence that points to a negative correlation between country income level and dependency on ecosystem services. Accounting for indirect dependencies on ecosystem services via supply chains and trade could change this observed relationship, however. Furthermore, the highest dependencies on ecosystem services across countries tend to be on climate regulation and flood and storm protection, indicating the interconnectedness of climate change and nature loss.

This paper is a product of the Finance, Competitiveness and Innovation Global Practice. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://www.worldbank.org/prwp. The authors may be contacted at pcalice@worldbank.org, fdiazkalan@worldbank.org, ndunz@worldbank.org, fmiguelliriano@worldbank.org.

Biodiversity and Finance: A Preliminary Assessment of Physical Risks for the Banking Sector in Emerging Markets

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JEL Classification: Q57, G21.
Keywords: Biodiversity, Green Finance,
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[1] This study has benefited from the comments by Giovanni Ruta, Etienne Espagne, Loic Chiquier (all World Bank) and Sebastian Bekker (UNEP-WCMC). The authors are with the World Bank. We are grateful to Camila Gutierrez and Juan Pablo Afanador for outstanding research assistance. This paper's findings, interpretations, and conclusions are entirely those of the authors and do not necessarily represent the views of the World Bank, its Executive Directors, or the countries they represent. All errors and omissions are ours.

1. Introduction

Nature and biodiversity loss (hereafter nature loss) are increasingly considered as a potential source of financial risk (NGFS-INSPIRE 2022). Biodiversity is declining faster than at any time in human history, with unprecedented high extinction rates (IPBES 2019), while soil and land quality is continuously degrading (UNCDD 2022). More than 50 percent of global GDP is moderately or highly dependent on nature and the services it provides (WEF 2020). Yet, continuing degradation of the environment through unsustainable economic activity reduces the extent of ecosystems and their services. This is an existential issue as ecosystem services make human life possible by providing essential benefits from ecosystems.[2]

All sectors of the economy are directly or indirectly dependent on ecosystem services, for many of which substitution is costly or limited. The collapse of those ecosystem services could lead to substantial economic costs (Johnson et al. 2022). The financial sector finances firms that depend on ecosystem services while their activities may facilitate the degradation of nature. As such there is a dual relationship between biodiversity and the financial sector, so called 'double materiality' (European Commission 2019, Taeger 2021).

Nature loss can affect the financial system through two main channels: physical and transition risks (NGFS-INSPIRE, 2022, van Toor et al. 2020). Physical risks could play out via deteriorating ecosystem services that firms depend on. Physical risks could escalate to systemic risks in case of large-scale failure of ecological systems, with consequences for the entire economy. Transition risks might arise from sudden policy, technology, or consumer preference changes that would aim to impede nature-harming activities of firms, thus affecting financing institutions. Therefore, financial institutions have an indirect exposure to nature-related risks. Lower firm revenues and profits could increase the probability of default and loss-given-default. This has negative implications for credit, market, and operational risks, potentially threatening financial stability.

Nature loss and climate change mutually reinforce each other. Climate change is one of the biggest drivers of nature loss. For instance, ocean acidification as a consequence of climate change is the main cause for coral reef destruction, including its outstanding biodiversity. At the same time, nature loss exacerbates climate change and its impacts, as deforestation not only increases greenhouse gas (GHG) emissions but also reduces flood and storm protection. This implies that financial institutions already exposed to climate-related risks (Calice and Miguel 2021, Reinders et al. 2021, Barth et al. 2019, Noth and Schüwer 2018, Regelink et al 2017), may also face the combined effects arising from the interaction between biodiversity loss, climate change, and natural disasters.

Academics, practitioners, and central banks are increasingly recognizing the potential risks from nature loss for the financial system and have started to analyze potential impacts and policy implications (van Toor et al. 2020, Calice et al. 2021, Kedward et al. 2021, Svartzman et al. 2021, World Bank and BNM 2022,

[2] Those services include regulating services (such as regulation of floods, droughts, and land degradation), provisioning services (such as crops, fresh water, aquaculture, and timber), supporting services (such as photosynthesis, nutrient cycle, water cycle), and cultural services (such as recreational and other non-material benefits).

Power et al. 2022, Monnin 2022). A recent report by the Network of Central Banks and Supervisors for Greening the Financial System (NGFS), a group of central banks and supervisors committed to developing best practices to manage climate-related risks and mobilizing capital for green and low-carbon investments, offers a set of recommendations for financial regulators and supervisors with regard to nature loss (NGFS-INSPIRE, 2022). Those recommendations include (i) recognizing nature loss as a potential source of economic and financial risk; (ii) building skill and capacity to assess and address those risks; (iii) exploring options for supervisory actions on managing biodiversity-related risks and minimizing negative impacts on ecosystems; and (iv) helping build the necessary financial architecture for mobilizing investment for a biodiversity-positive economy. To further advance the currently nascent knowledge base for potential supervisory action, the NGFS launched a new task force on nature-related risks (NGFS 2022).

Yet, the assessment of nature-related financial risk exposure is still nascent and only a handful of central banks have done so. This paper expands the scope of such analyses by providing high-level assessments of nature-related financial risk exposure for 20 emerging market economies, relying on publicly available information and data. The approach in this paper follows pioneering efforts by De Nederlandsche Bank (van Toor et al., 2020), and subsequently by the World Bank (Calice et al.,2021), Banque de France and AFD (Svartzman et al., 2021), and Bank Negara Malaysia (World Bank and BNM, 2022). This report's analysis can offer initial insights into banks' exposure to possible nature-related physical risk for emerging market economies. However, given its high-level nature and prevailing data gaps, estimates in this paper should be treated as a starting point for more in-depth analysis that would rely on unpublished data from local authorities. Furthermore, shifting from exposure analysis to a comprehensive assessment of nature-related risks requires the development of relevant scenarios and a better understanding of sectoral and asset level economic and financial vulnerabilities, including the consideration of indirect impacts.

The analysis offers four key findings. First, nature-related financial risk exposure is generally high (above 50 percent on average) across the sample countries. Second, higher exposure tends to be negatively correlated with countries' income level, highlighting the relevance of economic structure. When considering more indirect dependencies on ecosystem services via supply chains and trade, this correlation might change, however. Third, the highest dependencies on ecosystem services across countries tend to be on climate regulation and flood and storm protection, indicating the interconnectedness of climate change and nature loss. Finally, high dependencies on ecosystem services are concentrated in few sectors, with construction and real estate explaining more than 20 percent of all banking sector dependencies.

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

2. Methodology and data

This paper conducts a multi-country assessment of the dependency of banking systems on ecosystem services in 20 emerging market economies. The analysis serves as an indication of banking sector exposure to nature loss, specifically to nature-related physical risks. In this section, we describe the data sources as well as the applied methodology.

A common way to assess banks' nature-related physical risk is to consider the system-wide loan portfolio allocation to different economic sectors, which depend to varying degrees on ecosystem services. Following van Toor et al. (2020) and Calice et al. (2021), this analysis uses the ENCORE database, which provides a list of 86 business processes that directly depend on 21 ecosystem services - 17 regulation and maintenance ecosystem services and 4 provision services (see Table 3).[3,4] ENCORE links economic activities to the dependencies they potentially have on ecosystem services and the impacts they potentially have on natural capital. This enables a detailed assessment of the interactions of the economy with the natural environment, which in turn allows assessing the banking sector's exposure to potential nature-related physical risks.

We use publicly available country-level data on bank credit to non-financial firms as of end-2020, typically provided by central banks. We built a database of those credit portfolios by economic sectors for a set of 20 emerging and frontier markets (see Table 1).[5] Using the World Bank income-based country classification, the sample consists of 6 lower-middle-income, 8 upper-middle-income, and 6 high-income countries; accounting for around 10 percent of global GDP (Figure 1). [6]

In order to link credit information with ecosystem service dependency, we first connect sectoral lending portfolios to the production processes that underlie each economic sector. We map economic sectors to production processes using the crosswalk between NACE (Rev.2)[7] and the production processes rated in ENCORE, which are grounded on GICS[8] developed by the UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC, developers of ENCORE). In case of multiple production processes linked to an economic sector, we apply equal weighting to match NACE economic sectors and GICS production processes. For countries in our sample that do not publish sectoral credit portfolio statistics according to the NACE classification, we rely on standard correspondence tables published by Eurostat to facilitate the mapping.[9] Given the wide range of countries, publicly reported data granularity

[3] The ecosystem services dependencies materiality ratings by ENCORE are based 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. For additional details see https://encore.naturalcapital.finance/en/data-and-methodology/methodology.

[4] To avoid double counting, ENCORE only lists direct potential dependencies and impacts of production processes on ecosystem services. That means that it does not account for impacts that occur through the supply chain.

[5] MSCI defines a list of emerging and frontier markets which is more extensive than our set of countries. However, data availability allowed us to analyze a limited number of countries only. To leverage highly granular data available for developing countries not included in MSCI's referenced list and to broaden the scope of the paper, we added countries (e.g., Honduras).

[6] The World Bank methodology uses gross national income (GNI) per capita data in U.S. dollars, converted from local currency using the World Bank Atlas method, which is applied to smooth exchange rate fluctuations.

[7] NACE (Nomenclature of Economic Activities) is the classification of economic activities in the European Union (EU). Its latest revision (Rev.2) was performed in 2008.

[8] Global Industry Classification Standard (GICS), a classification developed by a private data provider.

[9] See Eurostat - Reference and Management of Nomenclatures – Index of Correspondence Tables. Available at: https://ec.europa.eu/eurostat/ramon/index.cfm

differs, which affects the mapping quality.[10] Table 2 provides an overview of the publicly available data granularity for the number of economic sectors for each country. Given those data constraints, the estimates in this paper should be treated as a starting point for more in-depth analysis, yet they provide a general indication of banks' exposure to possible nature physical risk for multiple emerging market economies.

As in van Toor et al. (2020) and Calice et al. (2021), we provide two measures for gauging the dependency of banking systems to ecosystem services. First, we estimate the total share of credit that is exposed to each ecosystem service by a high or very high dependency materiality rating. This metric provides a full account of the financial system exposure to individual ecosystem services. However, it does not allow adding across ecosystem services as business processes are often dependent on multiple ecosystem services. Second, we account for high or very high dependencies on *at least one ecosystem service*, effectively addressing the additionality issue of the first method. Hence, elevated dependencies on diverse (or multiple) ecosystem services can be aggregated in a single metric. Box 1 presents an illustration of the estimation's steps for each approach.

Box 1 – Mapping production processes to banking sector lending

An example of how part of a loan portfolio can be assigned a rating for its ecosystem dependency is presented in Figure 2, which depicts the case for "Crop and animal production, hunting and related service activities", a NACE activity Division. Loans granted to this economic sector are linked to six different production processes using equal weighting, which in turn have their own ENCORE materiality rating. Figure 2 highlights in grey the example of one of these processes, "Large-scale rainfed arable crops", which depends very highly on three ecosystem services (groundwater; mass stabilization and erosion control; flood and storm protection -presented in red), highly on another 9, and less on another 7. With varying levels of materiality, this particular production process depends on 19 of the 21 ecosystem services reviewed by ENCORE. This mapping can be carried out for all the production processes associated to every sector to which the banking sector lends.

There is a considerable variation in the number of ecosystem services that support specific production processes. For instance, small-scale irrigated arable crops depend highly or very highly on most ecosystem services, with 13, while the production process of railway transportation relies highly on one ecosystem service only - mass stabilization erosion control. See Calice et al. (2021) for an illustration on the interrelation of production processes and number of ecosystem services with high or very high dependency.

Illustration of our exposure metrics based on Figure 2.

- *Method 1 – Total credit share exposed to each ecosystem service by materiality rating.* When measuring the dependency to ground water, each dollar a firm borrowed for the production process of large-scale rainfed arable crops would count as one, even though that production process also depends on many other ecosystem services. Adding across all firms' high or very high dependency on groundwater would then provide a full account of the financial system exposure to that individual ecosystem service. To

[10] Difference in data disaggregation is a prevalent issue in cross country studies focused on loan data by industry. For example, see IMF (2021).

avoid double-counting, exposures should be examined individually and cannot be aggregated across different ecosystem services. As noted by van Toor et al. (2020), these estimates should be considered as a lower bound as it only accounts for the first-order dependencies of an economic sector on ecosystem services.

- *Method 2 – Ecosystem services with high or very high dependencies.* This method gauges the total share of the portfolio with business processes that are highly or very highly dependent on at least one ecosystem service. Following the illustration in Figure 2, this is equivalent to assuming that the dollar borrowed by a firm in NACE division "Crop and animal production, hunting and related service activities" is equally distributed across six business processes associated to this economic sector. Some of these six processes will by highly (H) or very highly (VH) dependent on ecosystem services. For example, "Large-scale rainfed arable crops" depends VH on three ecosystems and H on another nine, and so the process is flagged as highly dependent. In the unlikely case that the other five business processes exhibited no H/VH dependency on any ecosystem service, then one-sixth of each dollar borrowed by a firm in this NACE division would count as dependent. This approximation is then replicated for all economic sectors, and the exposures can be added for the entire portfolio. A caveat is that this metric is related to a diverse range of ecosystem services and could underestimate the exposure of firms dependent on ecosystem services with lower materiality ratings. Figure 6 addresses this limitation by integrating all ecosystem service materiality ratings.

3. Estimating financial physical risks of biodiversity loss

This section presents the findings on countries' bank exposure to physical risks by comparing their dependency on ecosystem services.

Banks in our sample of emerging markets allocate around half of their total credit portfolio to firms whose business processes are highly or very highly dependent on one or more ecosystem services.[11] This metric appears to be negatively correlated with the countries' income level (Figure 3). In lower-middle-income economies, banks allocate on average 55 percent of the loans to firms subject to potential financial losses due to a deterioration of ecosystem services. Within this group, countries with the highest dependency are Mauritius (73 percent), Pakistan (60 percent), and Indonesia (52 percent). In upper-middle income countries the dependency is lower, at 47 percent on average. Additionally, upper-middle-income countries show a lower dispersion compared to other country groups, ranging from 56 percent in Argentina to 43 percent in the Russian Federation. High-income countries in our sample show on average the lowest direct exposure to nature loss, with 45 percent of banks' credit portfolios directed to firms highly or very highly dependent on one or more ecosystem services. Within that income group, Hungary exhibits the highest dependency at 52 percent and Chile the lowest at 37 percent.[12]

[11] We use the high or very high to one or more ecosystem services metric to allow for comparability with available literature. We present alternative metrics in Table 5 in the Appendix.

[12] As highlighted before, this paper is based on publicly available data, and thus the results may only be interpreted as a broad indication that would require more in-depth and detailed assessment, relying on unpublished data from local authorities. For instance, Banco de Mexico estimates a comparable dependency metric at 36.5 percent using

The highest materiality ecosystem services are concentrated within a few economic sectors across our sample. In particular, six economic sectors represent a combined share of 60 percent of the exposures linked to high or very high dependencies (construction and real estate; crop and animal production; wholesale and retail trade; manufacture of food products; and electricity, gas, and other utilities). Among them, construction and real estate is the most exposed, making up more than 20 percent of all sector dependencies (Figure 5).[13] This can be explained as both sectors are generally a large share of bank lending, especially in fast growing emerging market economies, while they are highly dependent on abundant surface and ground water.

The negative correlation of dependency to income status is expected and seems to be related to the economic structure of those countries. Lower income countries usually have a higher share of the agriculture sector in their economy, which directly depends on multiple ecosystem services. Conversely, higher income countries in our sample have a larger service sector, which depends less directly on ecosystem services and thus exhibits lower exposures to physical risks (Figure 3 – Panel C). It should be noted, however, that ENCORE only captures direct dependencies, while indirect dependencies via supply chains and international trade cannot be assessed. Environmental footprint analysis captures such indirect dependencies by assessing the resource use of goods and services at consumption level. The environmental footprints of advanced economies are usually higher than the ones for emerging markets and developing economies (EMDEs) (Global Footprint Network 2022). This indicates that also less directly dependent economies could potentially be exposed to nature-related physical risks.

Across our sample, climate regulation, flood and storm protection, surface water, and groundwater, are the ecosystem services of highest dependency for banks' portfolios (see Figure 4). This finding is in line with the studies analyzing financial sector exposure in Brazil (Calice et al.,2021), Netherlands (van Toor et al., 2020) and France (Svartzman et al., 2021). Of every dollar that banks lend to corporates, 31 and 21 cents are either highly or very highly dependent on climate regulation, and flood and storm protection, respectively. Both services are essential for climate mitigation and adaptation, demonstrating the close linkages between nature loss and climate change. Mauritius, India, and the United Arab Emirates have a particularly high exposure to those ecosystem services (Figure 6).

Banks' portfolios in lower-income countries are more exposed to water-related ecosystem services. These differences are more evident in the case of surface and groundwater. For instance, of every dollar that banks lend to firms, 26 cents are either highly or very highly dependent on surface water in lower-middle-income countries. This compares to 20 cents per dollar in the case of upper-middle-income and 12 cents per dollar for high-income countries. The divergence is on a similar order of magnitude for groundwater but to a lower extent for water quality and water flow maintenance (Figure 7). Pakistan, Argentina, and

loan-level data and daily regulatory reports of all securities held at the security issuance level (NGFS-INSPIRE, 2022). Using significantly more aggregated information, our estimate is 6 percentage points lower.

[13] It should be noted that the indicated dependencies on the global sectoral averages are from the ENCORE database. However, ecosystem service dependencies may vary depending on the project design and should ultimately be evaluated at the project level. For example, a real estate investment that adheres to the passive house standard (a green building standard) may rely much less on ecosystem services such as water compared to traditional real estate projects.

Türkiye exhibit the largest exposure to surface water and ground water, which could potentially materialize as risk given the topography of those countries.

This analysis only focuses on high or very high exposure to ecosystems to allow for comparability with the literature. Table 5 shows how changes in some of the above-mentioned criteria would impact our results. For example, the system-wide exposure in lower-middle-income economies would fall from 55 percent to 11 percent if at least three high or very high dependencies are considered. These reflect that relatively less production processes are high/very high dependent on multiple ecosystem services. However, it should be noted that an isolated collapse of ecosystem services is relatively unlikely given that multiple ecosystem services depend on the same underlying ecosystem and the interconnectedness of ecosystems.

The critical dependency levels on ecosystem services (e.g., very low, low, medium, high, or very high) that could pose a material physical risk to the financial system are still unknown and might differ across countries, sectors, and firms. A large number of production processes present medium dependency on several ecosystem services, which may point to greater systemic vulnerability beyond the headline figures posted by high/very high dependencies. For example, exposure would increase from 55 percent to 79 percent if very high, high, and medium dependencies are included in the calculations (Table 5). This indicates the multiple entry points for risk transmission into the economy and highlights the importance to consider not only ecosystem services but the state of the underlying ecosystems and their interlinkages to assess potentially systemic risks.

To move from an exposure to a proper risk assessment, a better understanding of the resilience of countries' ecosystems to continuously provide ecosystem services is needed. Likewise, knowledge gaps prevail regarding the substitutability of different ecosystem services across and within different economic sectors (either by modifying production processes or replacing them altogether). Enhancing models and scenarios would allow for a more detailed examination of the financial risks associated with nature loss, enabling a more precise and situational regulatory and supervisory response (Almeida et al. 2023).

4. Concluding remarks

This paper provides a high-level assessment of nature-related physical risk exposure of banking sectors in 20 emerging market economies. The analysis is high level and relies on publicly available data and should thus be treated as such. Nevertheless, the analysis may give a general indication of the exposure of banking portfolios across multiple countries.

The analysis provides important insights for policy makers and supervisors. First, the exposure to potential nature-related financial risk is high, on average above 50 percent in the sample countries. Yet, it should be noted that this only includes direct dependencies. When accounting for indirect dependencies across supply and value chains, dependencies are likely to be higher. Second, the analysis indicates heterogenous exposure across countries and economic sectors, with Mauritius (73 percent), Pakistan (60 percent), and Argentina (55 percent) showing the highest potential direct dependency on ecosystem services in their banking credit portfolios. The lowest dependencies can be observed in Chile (37 percent) and the United Arab Emirates (41 percent). In general, higher exposure is negatively correlated with the countries' income

level, which points to the relevance of the structure of the economy. Accounting for indirect dependencies on ecosystem services via supply chains and trade could change this observed relationship, however. Third, dependencies across countries are highest for ecosystems services that provide climate regulation and flood and storm protection. This indicates the strong interdependencies between climate and nature-related financial risks. Finally, most material ecosystem services are concentrated around a few economic sectors, with construction and real estate explaining more than 20 percent of all banking sector dependencies.

The high-level analysis can already provide some insights on potential bottlenecks and sectors where policy makers and supervisors might want to investigate further and ultimately take action. However, it is important to have realistic expectations as to the ultimate policy objective. Attempting to reduce the dependency on nature and its ecosystem services might be prone to failure given the embeddedness of economies in nature (Dasgupta et al. 2021) and the reliance on goods and services that are directly provided by nature (e.g. agricultural products). The objective should rather be to induce a transformative shift from nature extracting and harming economic activities towards nature-positive activities and production processes (OECD 2019, Leclere et al. 2020, Power et al. 2022, World Bank Group 2021). For instance, intensive agriculture can have detrimental impacts on soil, biodiversity and terrestrial and maritime habitats (Benton et al. 2021). In contrast, more sustainable agricultural practices might be able to reduce those negative impacts. However, both types of agriculture, intensive and sustainable ones, would still remain highly dependent on nature. As such, there is a need to reduce the negative impact on ecosystems to ensure that ecosystem services could continuously support economic activity and human life in the future. There is a wide range of available policy tools in this regard, ranging from incentives and financial instruments for restoration activities and implementation of nature-based solutions over payment for ecosystem services to environmental tax reform and phasing out of nature-harming subsidies (Power et al. 2022).

The analysis provided in this paper can serve as a first step towards a fully-fledged nature risk assessment. Such an assessment would need to overcome currently persisting knowledge gaps, however (see NGFS-INSPIRE 2022, Karoly and de la Puente 2022, and Power et al. 2022 for more details). Those include i) a better understanding of economic and financial vulnerabilities, ii) the development of nature-related risk scenarios (NGFS 2022, Maurin et al 2022, Almeida et al. 2023), iii) the ongoing development of models that could quantitatively assess direct and indirect economic and financial impacts of nature loss (Johnson et al. 2021), and iv) and a better understanding of how to include those insights into the regulatory and supervisory framework (Stewart et al. 2022) and firms' decision making (TNFD 2022).

References

Almeida, E., Senni, C. C., Dunz, N. 2023. Building blocks for central banks to develop nature scenarios. INSPIRE Sustainable Central Banking Toolbox Policy Briefing Paper No. 11.

Barth, J. R., Sun, Y., and Zhang, S. 2019. Banks and Natural Disasters. SSRN Electronic Journal

Benton, T., Bieg, C., Harwatt, H., Pudasaini, R., Wellesley, L. 2021. Food system impacts on biodiversity loss: Three levers for food system transformation in support of nature. Research Paper. Chatham House. London, UK.

Calice, P. and F. Miguel. 2021. Climate-related and Environmental Risks in the Banking Sector in Latin America and the Caribbean: A Preliminary Assessment. Washington, DC.

Calice, P., Diaz Kalan, F. A., & Miguel, F. 2021. Nature-Related Financial Risks in Brazil. Policy Research Working Paper no. WPS 9759. World Bank Group, Washington, D.C.

Dasgupta, P. 2021. The Economics of Biodiversity: The Dasgupta Review. London: HM Treasury.

European Commission. 2019. Communication from the commission: Guidelines on non-financial reporting: Supplement on reporting climate-related information. European Commission. Brussels, Belgium.

Global Footprint Network. 2021. Ecological Footprint. Webpage. Accessed on October 15, 2022. https://www.footprintnetwork.org/our-work/ecological-footprint/

IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services). 2019. The Global Assessment Report on Biodiversity and Ecosystem Services: Summary for Policymakers. Bonn, Germany: IPBES.

Johnson, J. A., G. Ruta, U. Baldos, R. Cervigni, S. Chonabayashi, E. Corong, O. Gavryliuk, J. Gerber, T. Hertel, C. Nootenboom, and S. Polasky. 2021. The Economic Case for Nature: A Global Earth-Economy Model to Assess Development Policy Pathways. Washington, D.C.: World Bank. https://openknowledge.worldbank.org/handle/10986/35882 . License: CC BY 3.0 IG

Karolyi, G. and Tobin-de la Puente, J., 2022. Biodiversity Finance: A Call for Research into Financing Nature. Available at SSRN: https://ssrn.com/abstract=4142482 or http://dx.doi.org/10.2139/ssrn.4142482

Kedward, K., Buller, A. and Ryan-Collins, J. 2021. Quantitative easing and nature loss: exploring nature-related financial risks and impacts in the European Central Bank's corporate bond portfolio. UCL Institute for Innovation and Public Purpose. IIPP Policy Report (IIPP 2021/02).

Leclère, D., Obersteiner, M., Barrett, M., Butchart, S. H. M., Chaudhary, A., De Palma, A., DeClerck, F. A. J., Di Marco, M., Doelman, J. C., Dürauer, M., Freeman, R., Harfoot, M., Hasegawa, T., Hellweg, S., Hilbers, J. P., Hill, S. L. L., Humpenöder, F., Jennings, N., Krisztin, T., … Young, L. 2020. "Bending the curve of terrestrial biodiversity needs an integrated strategy". Nature, 585(7826), 551–556. https://doi.org/10.1038/s41586-020-2705-y.

Maurin, J., Calas, J., Godin, A., Espagne, E. 2022. Global biodiversity scenarios: what do they tell us for biodiversity-related socio-economic impacts?. AFD Policy Paper. Paris, France.

Natural Capital Finance Alliance. 2021. ENCORE: Exploring Natural Capital Opportunities, Risks and Exposure. Cambridge, UK: Natural Capital Finance Alliance. https://doi.org/10.34892/dz3x-y059.

NGFS-INSPIRE. 2022. Central banking and supervision in the biosphere: An agenda for action on biodiversity loss, financial risk and system stability Final Report of the NGFS-INSPIRE Study Group on Biodiversity and Financial Stability. NGFS Occasional Paper

NGFS. 2022. Statement on Nature-Related Financial Risks.

Noth, F., and Schüwer, U. 2018. Natural Disaster and Bank Stability: Evidence from the US Financial System.

OECD (2019), Biodiversity: Finance and the Economic and Business Case for Action, OECD Publishing, Paris, https://doi.org/10.1787/a3147942-en.

Power, S., Dunz, N., and Gavryliuk, O. 2022. An Overview of Nature-Related Risks and Potential Policy Actions for Ministries of Finance: Bending the Curve of Nature Loss. Coalition of Finance Ministers for Climate Action, Washington, D.C. © Coalition of Finance Ministers for Climate Action.

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

Regelink, M., Reinders, H. J., Vleeschhouwer, M., and van de Wiel, I. 2017. Waterproof? An Exploration of Climate-related Risks for the Dutch financial sector. De Nederlandsche Bank.

Stewart, E., Power, S., Wadhwa, B., Kumar, M., Flugge, M., Swann, S. and Nassiry, D. 2022. Sovereign Climate and Nature Reporting : Proposal for a Risks and Opportunities Disclosure Framework (English). Washington, D.C. : World Bank Group.

Svartzman, R., Espagne, E., Gauthey, J., Hadji-Lazaro, P., Salin, M., Allen, T., ... & Vallier, A. A. 2021. "Silent Spring" for the Financial System? Exploring Biodiversity-Related Financial Risks in France.

Täger M (2021) 'Double materiality': what is it and why does it matter? Commentary. London: Grantham Research Institute on Climate and the Environment, London School of Economics. https://www.lse.ac.uk/granthaminstitute/news/double-materiality-what-is-it-and-whydoes-it-matter/

Taskforce for Nature-related Financial Disclosures (TNFD). 2022. The TNFD Nature-related Risk and Opportunity Management and Disclosure Framework Beta v0.3 Summary.

United Nations Convention to Combat Desertification (UNCDD) 2022. Global Land Outlook 2nd Edition. https://www.unccd.int/resources/global-land-outlook/global-land-outlook-2nd-edition .

Van Toor, J., D. Piljic, G. Schellekens, M. van Oorschot, and M. Kok. 2020. “Indebted to Nature: Exploring Biodiversity Risks for the Dutch Financial Sector.” Amsterdam: DNB (De Nederlandsche Bank).Wendling, Z. A., Emerson, J. W., de Sherbinin, A., Esty, D. C., et al. (2020). 2020 Environmental Performance Index. New Haven, CT: Yale Center for Environmental Law & Policy

WEF (World Economic Forum). 2020. Nature Risk Rising: Why the Crisis Engulfing Nature Matters for Business and the Economy. Geneva: WEF.

World Bank and BNM (Bank Negara Malaysia). 2022. An Exploration of Nature-Related Financial Risks. Kuala Lumpur: World Bank.

World Bank Group. 2021. Unlocking Nature-Smart Development: An Approach Paper on Biodiversity and Ecosystem Services. World Bank, Washington, DC. © World Bank. https://openknowledge.worldbank.org/handle/10986/36047 License: CC BY 3.0 IGO.

Appendix

A. Figures

Figure 1 – Countries covered in the analysis.

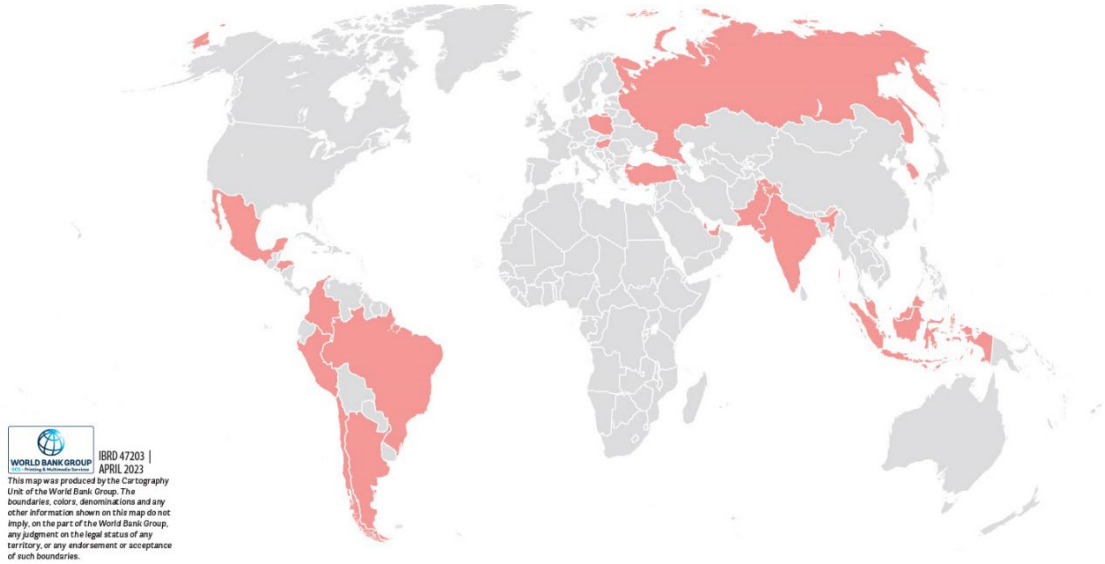
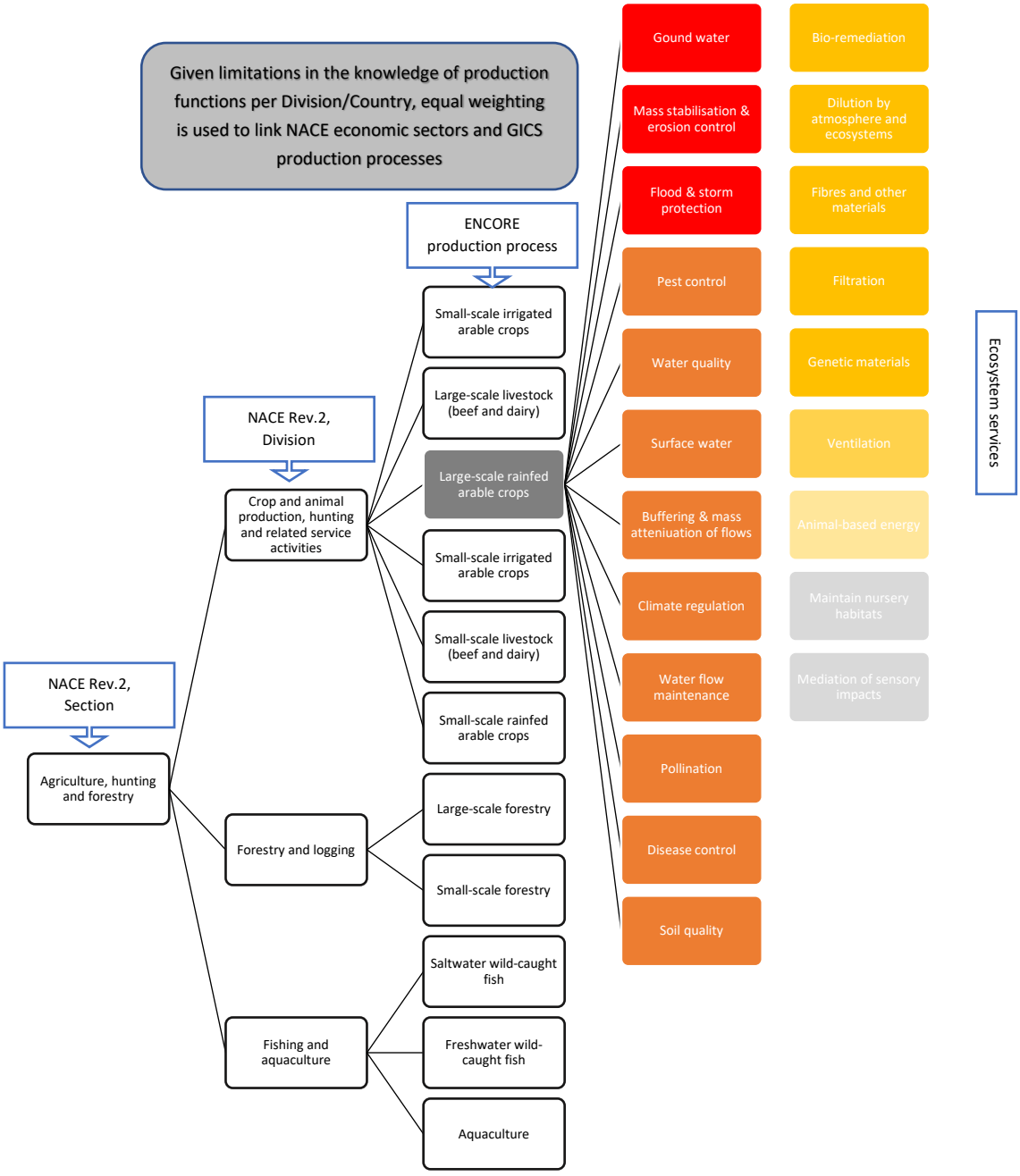


Figure 2 – Example of ENCORE materiality of a production process dependencies on ecosystems, large-scale irrigated arable crops

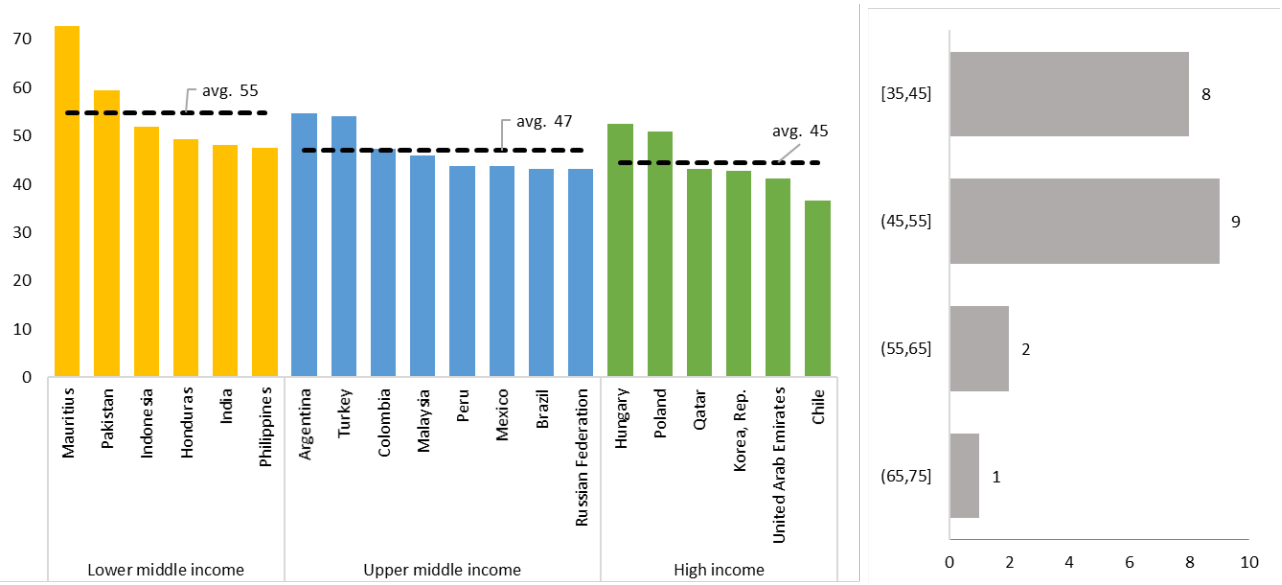


Source: Calice, Diaz Kalan, Miguel (2021) based on Natural Capital Finance Alliance, UNEP-WCMC - ENCORE. **Note**: In red very high dependency, in orange high dependency, in yellow medium dependency (with lighter shades for low and very low), grey shows no dependency.

Figure 3 - Processes with high/very high dependency materiality

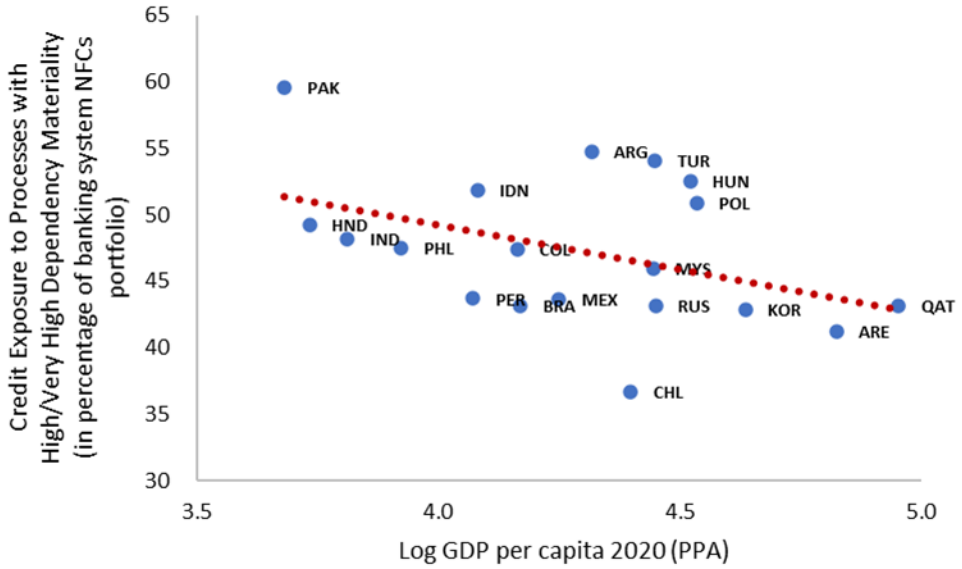
Panel A - Credit exposure to processes with high/very high dependency materiality (in percentage of banking system NFCs portfolio)

Panel B - Histogram of panel A (number of countries)



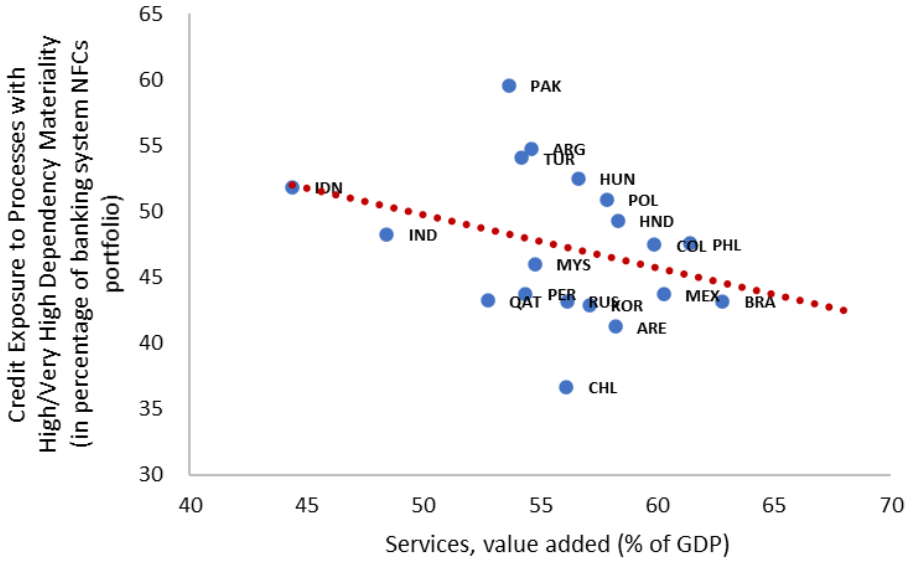
Source: own elaboration based on ENCORE and local authorities.

Panel B - Credit exposure to processes with high/very high dependency materiality (in percentage of banking system NFCs portfolio) and GDP per capita (Log, PPA 2020)



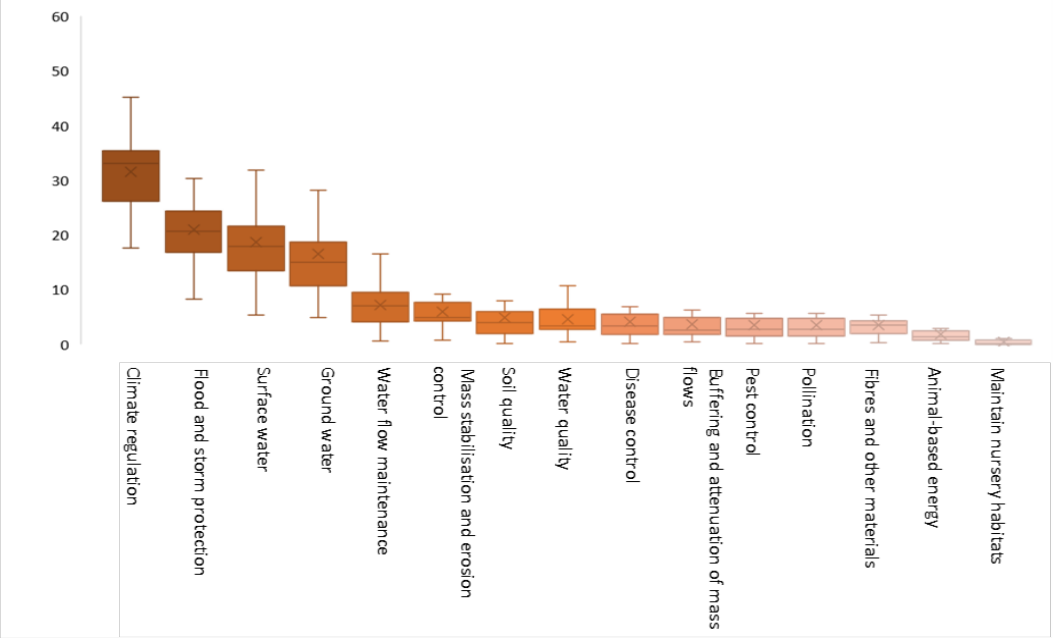
Source: own elaboration based on ENCORE, local authorities, and World Development Indicators (WB). **Note:** Excludes Mauritius for presentation purposes (exposure of 73 percent). The dotted line is the resulting linear fitted trend.

Panel C - Credit exposure to processes with high/very high dependency materiality (in percentage of banking system NFCs portfolio) and Services value added as percentage of the GDP 2020.



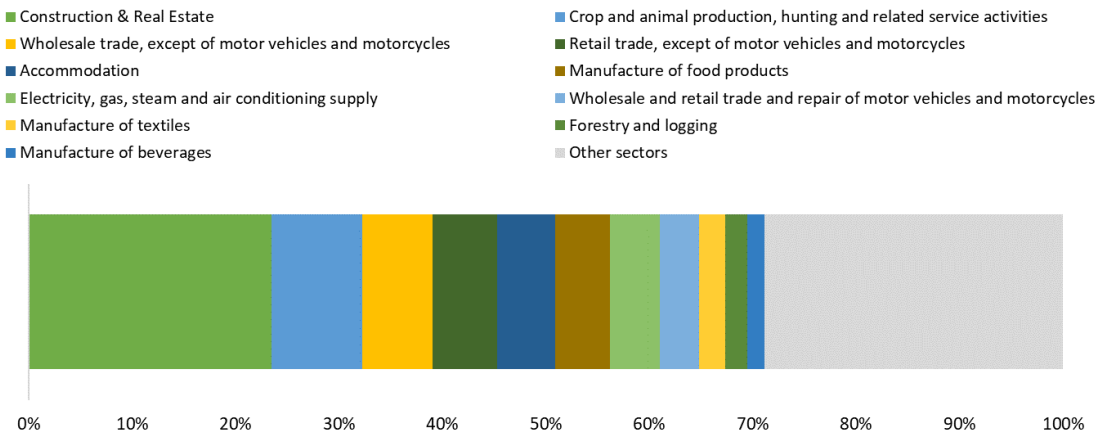
Source: own elaboration based on ENCORE, local authorities, and WB – World Development Indicators. **Note:** Excludes Mauritius for presentation purposes (exposure of 73 percent). The dotted line is the resulting linear fitted trend.

Figure 4 – Credit exposure to processes with high/very high dependency materiality by ecosystem service (in percentage of banking system NFCs portfolio)



Source: own elaboration based on ENCORE and local authorities. **Note**: Full sample of countries. Excludes outlier values. The limits of the internal box are the first and third quartiles with the band inside representing the median. The upper whisker represents the highest value still within 1.5 times the interquartile range (IQR) of the upper quartile. The lower whisker represents the lowest value still within 1.5 times the IQR of the lower quartile.

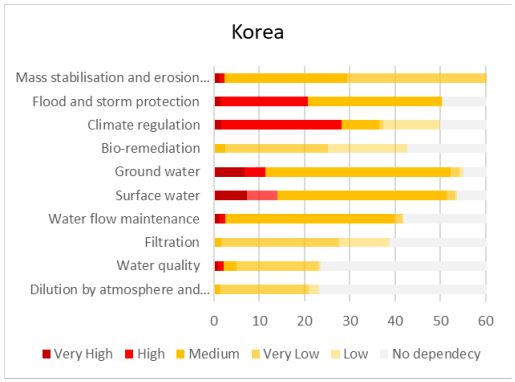
Figure 5 – Relative lending exposure to NACE sectors with high or very high dependencies

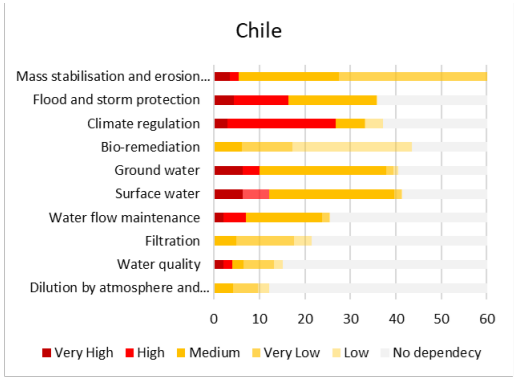


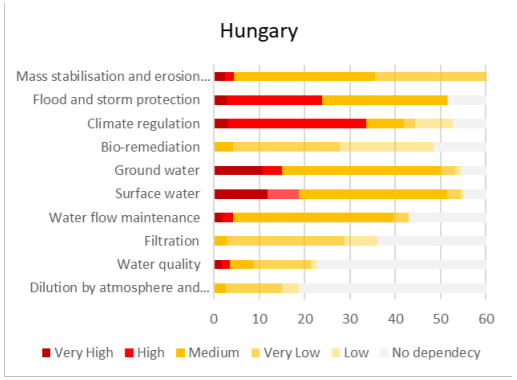
Source: own elaboration based on ENCORE and local authorities. **Note**: Full sample of countries according to NACE Rev.2 classification, 2-digits level. Given data limitations, loans for construction activities (NACE 41/42/43) and real estate (NACE 68) were grouped into a single category (Construction & real estate). We follow a conservative approach for the calculation of this exercise; that is, the total amount of this group is associated only with the ecosystem services with H/VH dependency.

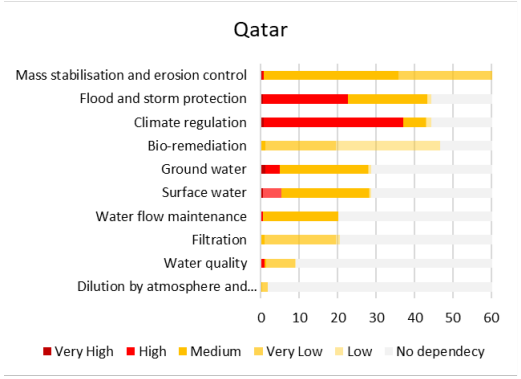
Figure 6 – Credit to Non-financial Corporates: Dependency of the Banking System Portfolio to Individual Ecosystem Services (in percentage)

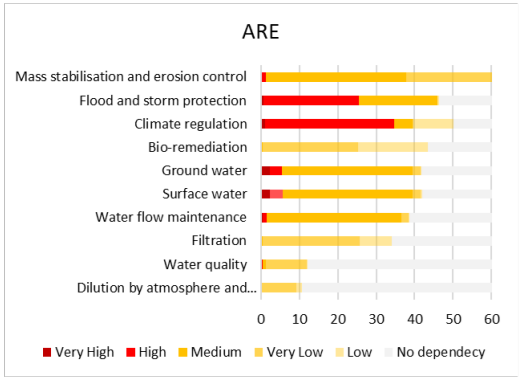
Panel A - High income countries

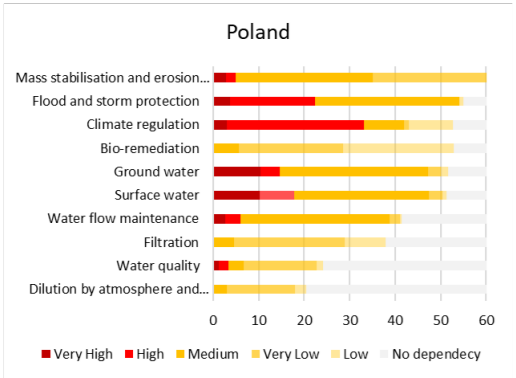




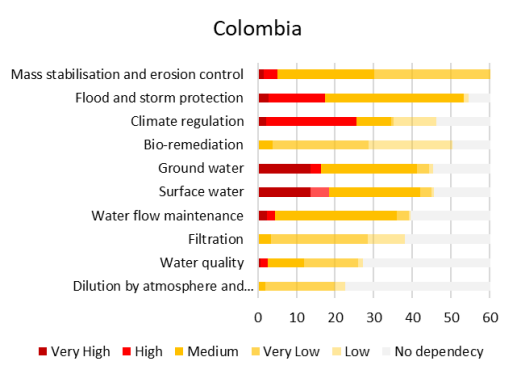


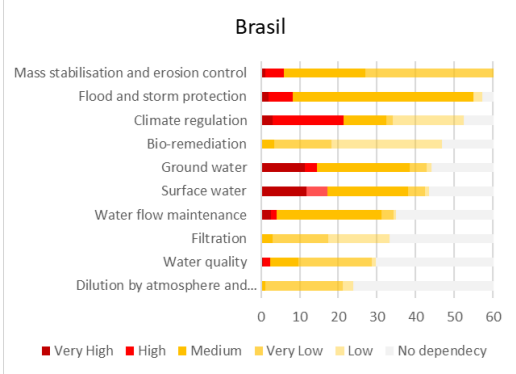


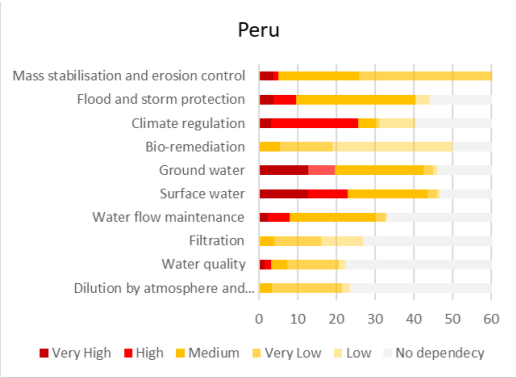


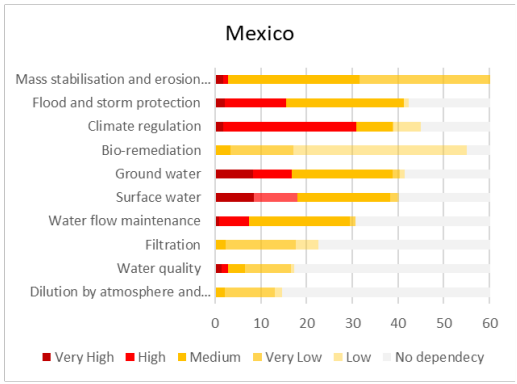


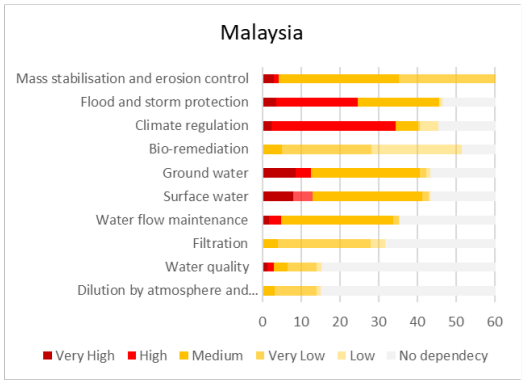
Panel B – Upper middle-income countries

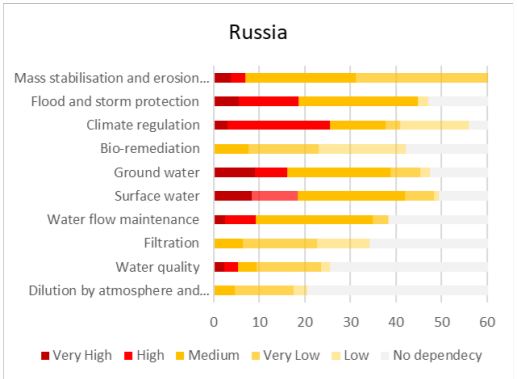


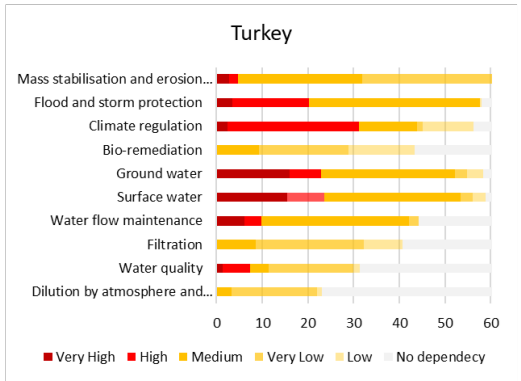


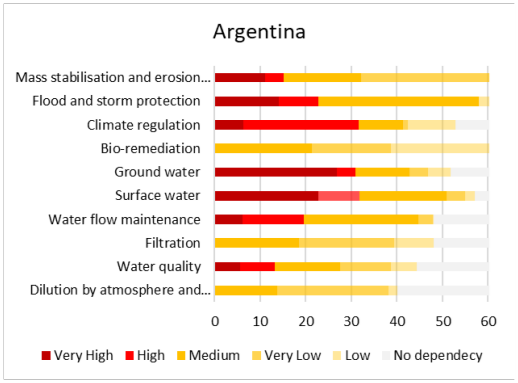




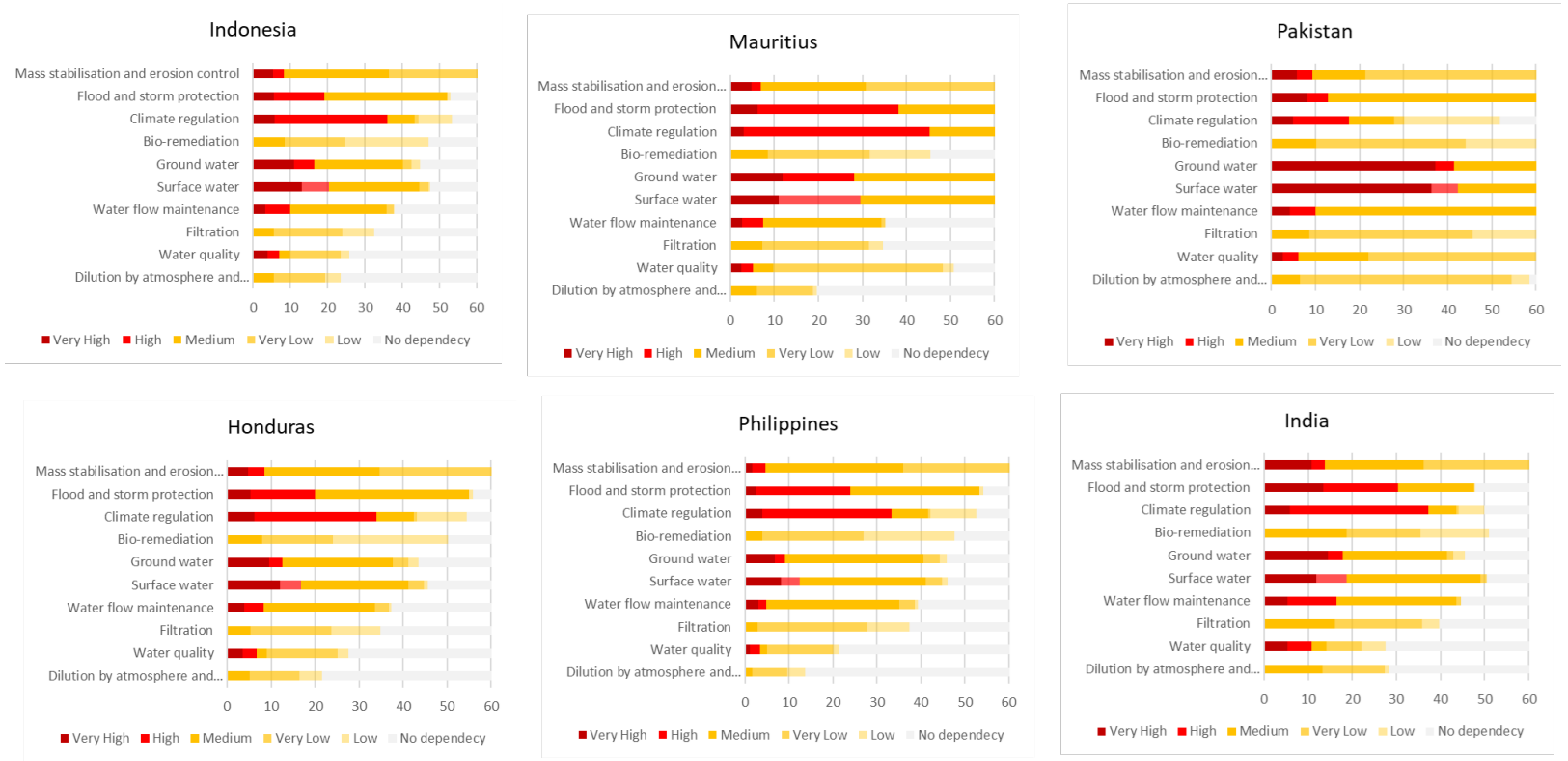






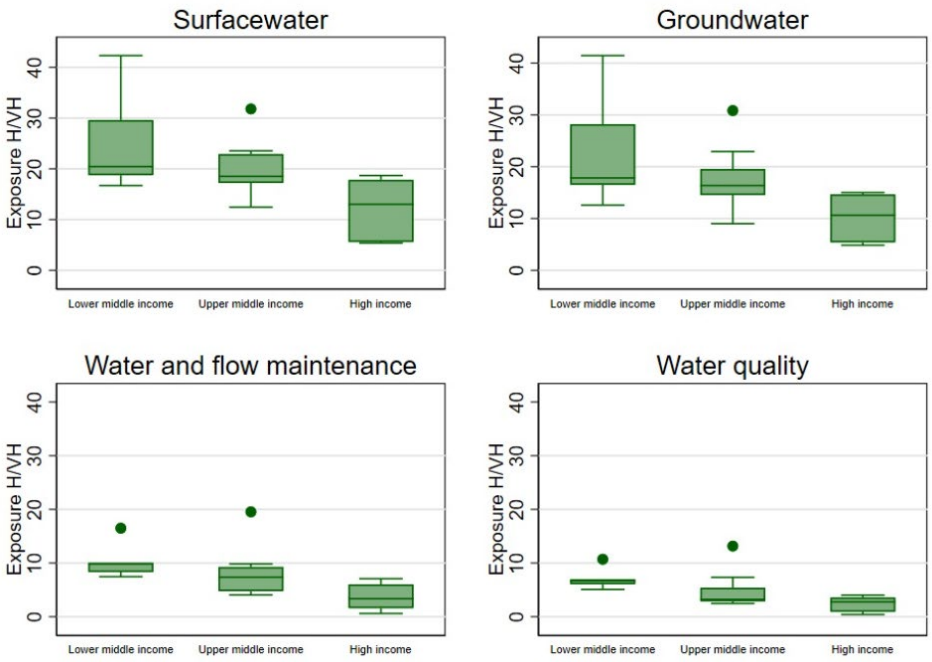


Panel C – Lower middle-income countries



Source: own elaboration based on ENCORE and local authorities. For presentation purposes, we trimmed the x-axis to 60 percent.

Figure 7 – Credit exposure to processes with high/very high dependency materiality by water-related ecosystem services (in percentage of banking system NFCs portfolio)



Source: own elaboration based on ENCORE and local authorities.

B. Tables

Table 1 - Data Sources

Data / Description	Country / Source
Credit outstanding / End-of-period balance of credit operations outstanding by economic sector. Data as of December 2021.	Brazil / Banco Central do Brasil
	Chile / Comisión para el Mercado Financiero
	Colombia / Superintendencia Financiera de Colombia
	Mexico / Comisión Nacional Bancaria y de Valores
	Peru / Superintendencia de Banca, Seguros y AFP
	Honduras / Comision Nacional de Bancos y Seguros
	Hungary / The Central Bank of Hungary
	Lithuania / Bank of Lithuania
	Poland / Polish Financial Supervision Authority
	Russian Federation / Bank of Russia
	Serbia / National Bank of Serbia
	Estonia / Eesti Pank
	Türkiye / Banking Regulation and Supervision Agency
	Greece / Bank of Greece
	Indonesia / Bank Indonesia
	Korea, Rep. / Bank of Korea
	Philippines / Central Bankn of the Phillipines
	Thailand / Bank of Thailand
	Malaysia / Central Bank of Malasya
	India / Reserve Bank of India
	Pakistan / State Bank of Pakistan
	United Arab Emirates / Central Bank of the U.A.E
	Qatar / Qatar Central Bank
	Mauritius / Bank of Mauritius
Dependency Materiality Rating / Materiality of production processes' dependencies to biodiversity services. Classification standards are GICS (for production processes) and CICES (for ecosystem services).	ENCORE / Developed by Natural Capital Finance Alliance in cooperation with UNEP-WCMC; UNEP-WCMC and NCFA.

Note: The selection of countries follows the MSCI definition of emerging and frontier markets. See https://www.msci.com/our-solutions/indexes/emerging-markets

Table 2 – Sample composition and underlying data quality

The mapping quality of the production processes' dependency on ecosystem services is intrinsically dependent on the granularity of the economic sector disaggregation available of banks' credit outstanding data in each country. In the table below, "Underlying data quality" refers to the number of economic sectors available in each country. Green depicts countries with is more than 40 economic sector disaggregation, yellow between 20 and 40, and red is less than 20.

Country	Region	Income level	Underlying data quality
Indonesia	East Asia & Pacific	Lower middle income	
Honduras	Latin America & Caribbean	Lower middle income	
Philippines	East Asia & Pacific	Lower middle income	
India	South Asia	Lower middle income	
Mauritius	Sub-Saharan Africa	Lower middle income	
Pakistan	South Asia	Lower middle income	
Mexico	Latin America & Caribbean	Upper middle income	
Peru	Latin America & Caribbean	Upper middle income	
Brazil	Latin America & Caribbean	Upper middle income	
Colombia	Latin America & Caribbean	Upper middle income	
Argentina	Latin America & Caribbean	Upper middle income	
Türkiye	Europe & Central Asia	Upper middle income	
Russian Federation	Europe & Central Asia	Upper middle income	
Hungary	Europe & Central Asia	High income	
Poland	Europe & Central Asia	High income	
United Arab Emirates	Middle East & North Africa	High income	
Malaysia	East Asia & Pacific	Upper middle income	
Chile	Latin America & Caribbean	High income	
Korea, Rep.	East Asia & Pacific	High income	
Qatar	Middle East & North Africa	High income	

Source: own elaboration.

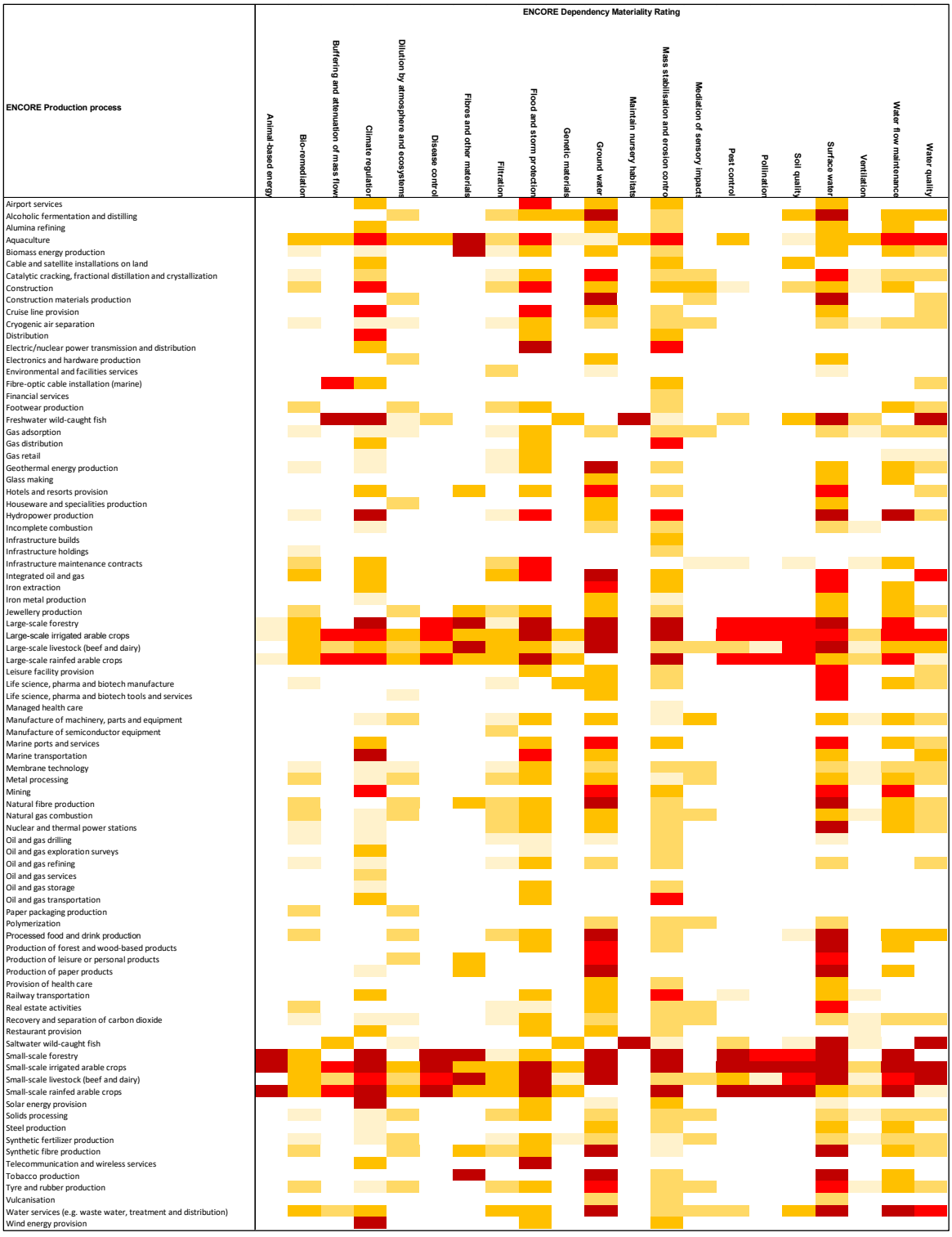
Table 3 – List of ecosystem services included in the ENCORE database

Ecosystem Service	Ecosystem service description
Animal-based energy	Physical labor is provided by domesticated or commercial species, including oxen, horses, donkeys, goats and elephants. These can be grouped as draught animals, pack animals and mounts.
Bio-remediation	Bio-remediation is a natural process whereby living organisms such as micro-organisms, plants, algae, and some animals degrade, reduce, and/or detoxify contaminants.
Buffering and attenuation of mass flows	Buffering and attenuation of mass flows allows the transport and storage of sediment by rivers, lakes and seas.
Climate regulation	Global climate regulation is provided by nature through the long-term storage of carbon dioxide in soils, vegetable biomass, and the oceans. At a regional level, the climate is regulated by ocean currents and winds while, at local and micro-levels, vegetation can modify temperatures, humidity, and wind speeds.
Dilution by atmosphere and ecosystems	Water, both fresh and saline, and the atmosphere can dilute the gases, fluids and solid waste produced by human activity.
Disease control	Ecosystems play important roles in regulation of diseases for human populations as well as for wild and domesticated flora and fauna.
Fibers and other materials	Fibers and other materials from plants, algae and animals are directly used or processed for a variety of purposes. This includes wood, timber, and fibers which are not further processed, as well as material for production, such as cellulose, cotton, and dyes, and plant, animal and algal material for fodder and fertilizer use.
Filtration	Filtering, sequestering, storing, and accumulating pollutants is carried out by a range of organisms including, algae, animals, microorganisms and vascular and non-vascular plants.
Flood and storm protection	Flood and storm protection is provided by the sheltering, buffering and attenuating effects of natural and planted vegetation.
Genetic materials	Genetic material is understood to be deoxyribonucleic acid (DNA) and all biota including plants, animals and algae.
Ground water	Groundwater is water stored underground in aquifers made of permeable rocks, soil and sand. The water that contributes to groundwater sources originates from rainfall, snow melts and water flow from natural freshwater resources.
Maintain nursery habitats	Nurseries are habitats that make a significantly high contribution to the reproduction of individuals from a particular species, where juveniles occur at higher densities, avoid predation more successfully, or grow faster than in other habitats.
Mass stabilization and erosion control	Mass stabilization and erosion control is delivered through vegetation cover protected and stabilizing terrestrial, coastal and marine ecosystems, coastal wetlands and dunes. Vegetation on slopes also prevents avalanches and landslides, and mangroves, sea grass and macroalgae provide erosion protection of coasts and sediments.
Mediation of sensory impacts	Vegetation is the main (natural) barrier used to reduce noise and light pollution, limiting the impact it can have on human health and the environment.

Pest control	Pest control and invasive alien species management is provided through direct introduction and maintenance of populations of the predators of the pest or the invasive species, landscaping areas to encourage habitats for pest reduction, and the manufacture of a family of natural biocides based on natural toxins to pests.
Pollination	Pollination services are provided by three main mechanisms: animals, water and wind. The majority of plants depend to some extent on animals that act as vectors, or pollinators, to perform the transfer of pollen.
Soil quality	Soil quality is provided through weathering processes, which maintain bio-geochemical conditions of soils including fertility and soil structure, and decomposition and fixing processes, which enables nitrogen fixing, nitrification and mineralization of dead organic material.
Surface water	Surface water is provided through freshwater resources from collected precipitation and water flow from natural sources.
Ventilation	Ventilation provided by natural or planted vegetation is vital for good indoor air quality and without it there are long term health implications for building occupants due to the build-up of volatile organic compounds (VOCs), airborne bacteria and moulds.
Water flow maintenance	The hydrological cycle, also called water cycle or hydrologic cycle, is the system that enables circulation of water through the Earth's atmosphere, land, and oceans. The hydrological cycle is responsible for recharge of groundwater sources (i.e. aquifers) and maintenance of surface water flows.
Water quality	Water quality is provided by maintaining the chemical condition of freshwaters, including rivers, streams, lakes, and ground water sources, and salt waters to ensure favorable living conditions for biota.

Source: ENCORE.

Table 4 – ENCORE Production Process and Ecosystem Services Dependency Mapping



Source: Calice et al. (2021). **Note**: Colors indicate materiality rating: ● Very High, ● High, ● Medium, ● Low, and ● Very Low.

Table 5 – Distribution of the Number of Ecosystem Services and Materiality Rating

Number of ecosystem services	Very High	Very High and High	Very High, High and Medium
High income countries			
At least 1	10%	**45%**	73%
At least 2	7%	30%	70%
At least 3	4%	5%	64%
Upper middle-income countries			
At least 1	18%	**47%**	70%
At least 2	15%	32%	66%
At least 3	7%	10%	61%
Lower middle-income countries			
At least 1	23%	**55%**	79%
At least 2	18%	41%	75%
At least 3	9%	11%	71%

Source: own elaboration based on ENCORE and local authorities. **Note**: In bold, we highlight the metric used throughout the document.