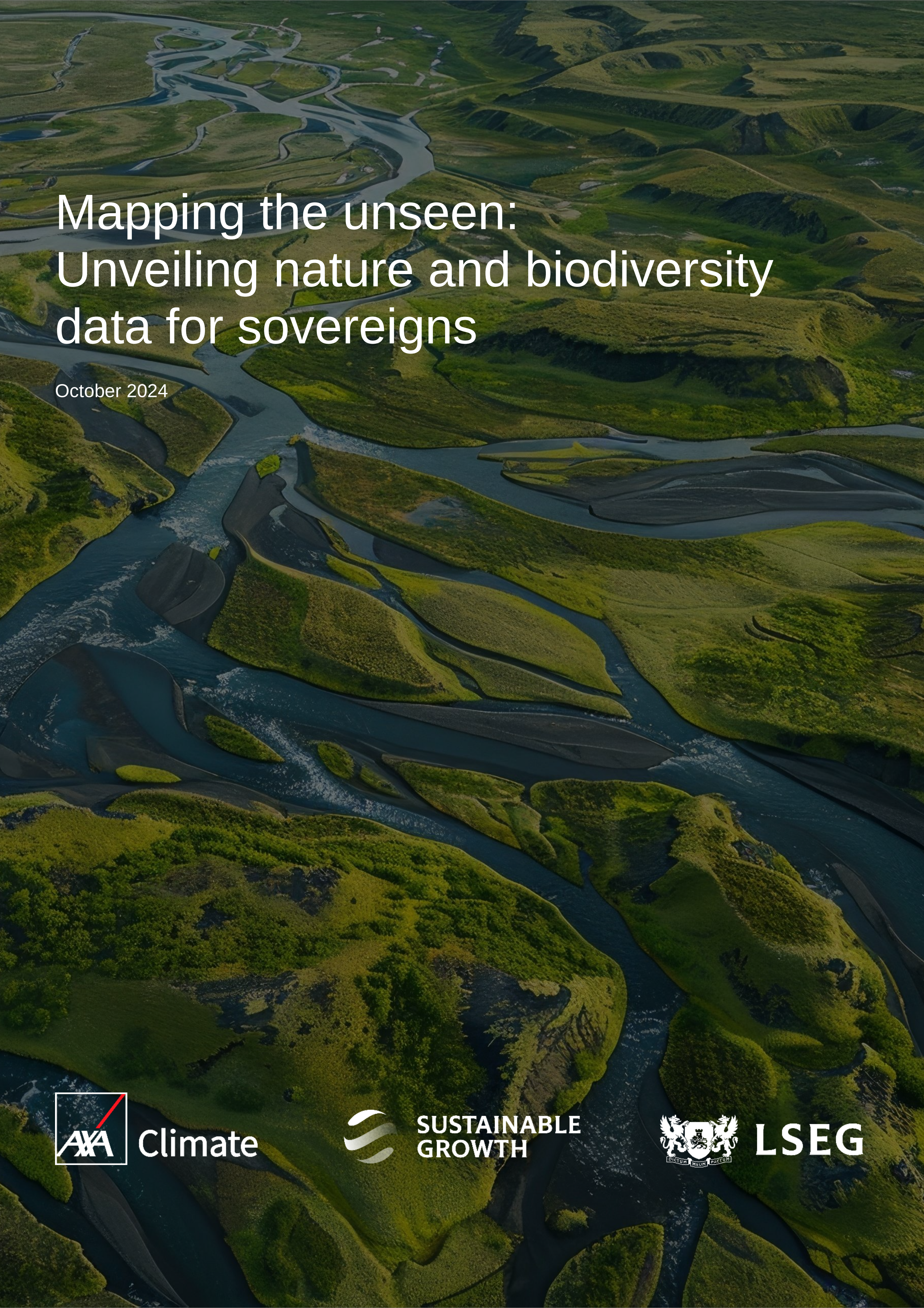
Mapping the unseen: Unveiling nature and biodiversity data for sovereigns

October 2024



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Nature and biodiversity topics are increasingly attracting the attention of corporate boards and investment committees as markets start to appreciate the multifaceted risks that environmental losses pose to businesses, investors and society. Despite rapid development, gaps in data continue to create challenges for the integration of nature-based solutions into investment strategies.

The September 2023 launch of the recommendations of the Taskforce on Nature-related Financial Disclosures (TNFD) gave rise to numerous initiatives around corporate assessment and disclosure of nature-related risks and opportunities. The sovereign side, however, is much less studied. Nature-related effects are fundamentally location-specific, which adds a layer of complexity when trying to assess nature at the country level.

To help investors start their journey towards nature analyses at the country-level, this report aims to

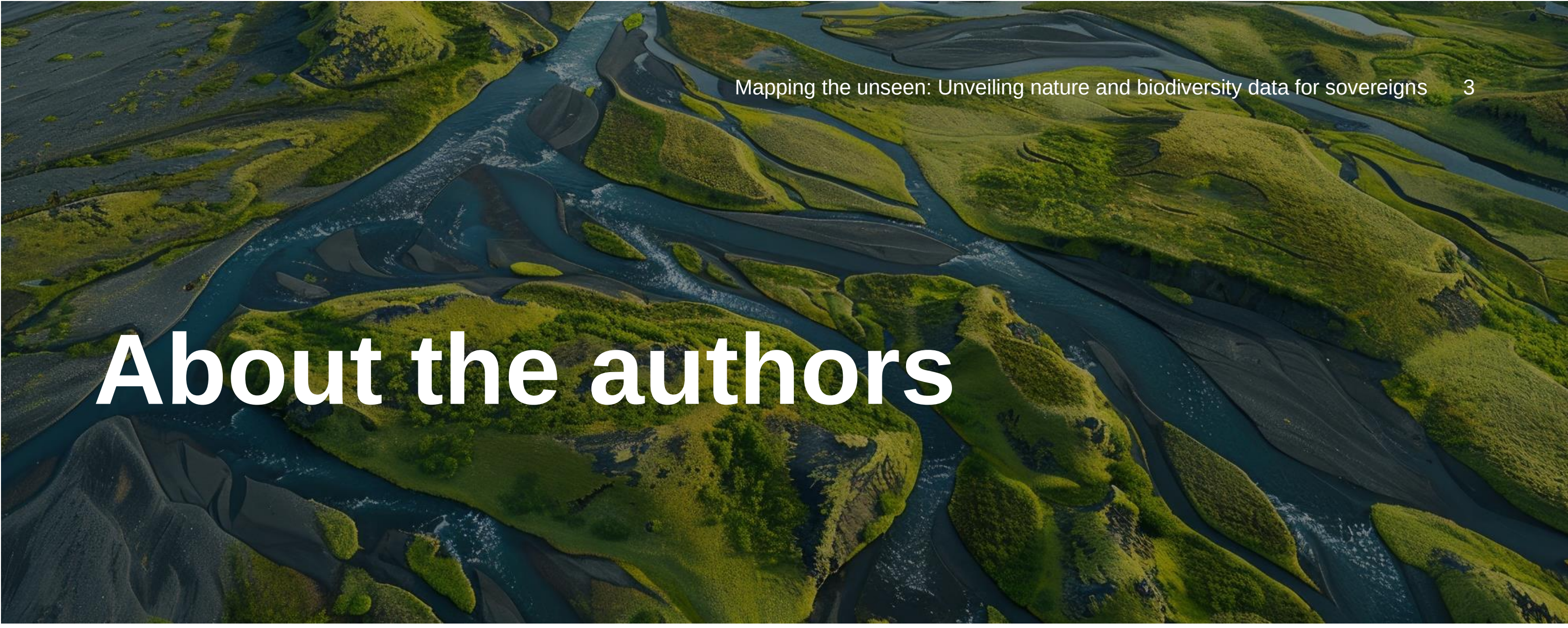
i. provide clarity on the main nature-related concepts;

ii. explain why nature is of major interest for sovereign investment;

iii. survey different datasets to highlight the need to evaluate nature-related risks and opportunities from a multi-dimensional perspective;

iv. highlight the challenges that investors face regarding country-level nature analyses.

Our research demonstrates that while country-level nature-related datasets are becoming more widely available, they come with a variety of challenges, including inconsistent coverage and complexity of use. This paper provides a useful guide to the available data and shows that selecting the relevant indicator for each use case is critical for accurately evaluating the risks and opportunities associated with nature in sovereign investing.



About the authors

Claire Hugo

Senior Associate, Sustainable Investment Data Models, LSEG

Claire is a subject-matter expert in SI data and methodologies, supporting multi-asset SI product development at FTSE Russell. She previously led sovereign nature-related research and contributed to all cross-functional activities on physical climate risks within the LSEG SI Research team.

Astrid Sofia Flores Moya

Senior Analyst, Sustainable Investment Research, LSEG

Astrid leads Sovereign ESG research at LSEG. Using her quantitative skillset and subject-matter expertise in socioeconomics, she produces methodologies, indicators and tools that help better capture countries' E, S and G risk and performance.

Florian Gallo

Senior Research Lead, Physical Climate Risks and Biodiversity, LSEG

Florian is a climate scientist with 10+ years of experience, with a background in earth sciences and nature hazards. He previously led the research on physical climate risks and nature and biodiversity at LSEG.

Geoffroy Dufay

Head of Nature products and analytics, AXA Climate

Geoffroy is responsible for nature products and analyses at AXA Climate. He leads the development of solutions to transform environmental and business data into risk assessments and opportunity evaluations, and subsequently into positive impact strategies.

Julie Rode

Nature Research Lead, AXA Climate

Julie leads the R&D for biodiversity risk assessments at AXA Climate. She works on the development of indicators and metrics to understand the state of nature, quantify threats on species, and model ecosystem services.

Raphael Marchand

Senior Nature Data Engineer, AXA Climate

Raphael is a senior data engineer specialized in the collection, management, and transformation of geospatial and environmental data. He previously worked on the development of a natural catastrophe monitoring tool to help companies face natural hazards.

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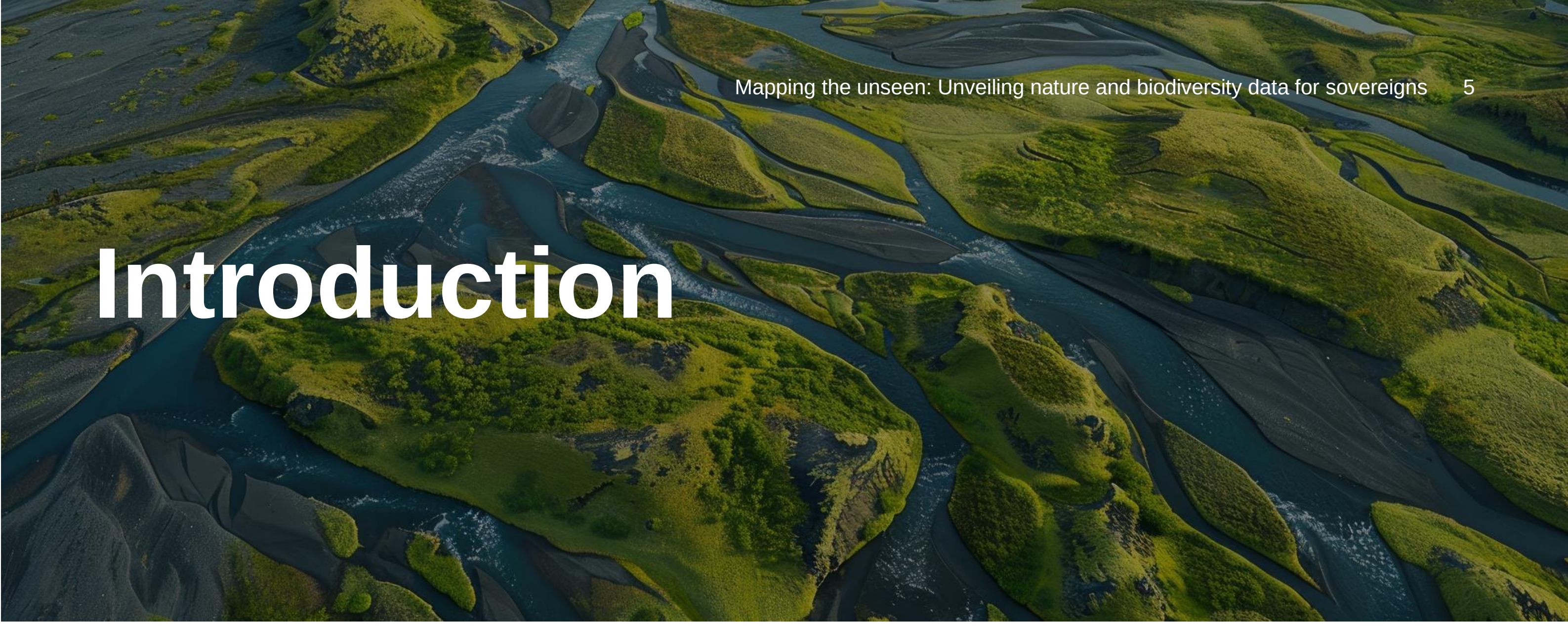


Introduction

Biodiversity describes the variability among living organisms from all sources, including terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part. This includes diversity within species, between species and of ecosystems.[1] 'Nature' is a broader term, though often associated and/or used interchangeably with biodiversity. It encompasses both the diversity of living organisms and their interactions among themselves and with their environment.[2]

Nature is at the heart of all anthropic systems and communities including the global economy. More than half of the global economy (around US$ 44 trillion) is estimated to be linked directly to nature.[3] Healthy and biodiverse ecosystems support a wide range of services, including the provisioning of natural resources, regulating of natural processes, and supporting of life. In addition, well preserved environments are a natural mitigation resource against climate hazards, contributing to coastal protection or storing carbon emissions.

GROWING PRESSURE ON GLOBAL NATURAL SYSTEMS AND RESOURCES

Ecosystems, under pressure from human activities, are experiencing record species extinction rates. The consequences of nature loss may be as varied as depletion of natural capital resources, supply chain disruption, decreases in crop yields due to an insufficient number of pollinators[4] or sanitary risks due to natural habitat shrinkage and closer contacts with animals.[5] The reduced supply of six of these ecosystem services in a business-as-usual scenario would already lead to a 0.67% drop in annual global GDP by 2050.[6]

Furthermore, six out of the nine planetary boundaries (climate change, biosphere integrity, land system change, freshwater change, biogeochemical flows (nitrogen and phosphorus and novel entities) have already been crossed,[7] threatening the planet's ability to sustain national economies. As in the climate system, cascading effects and tipping points could make most of the changes irreversible. Even in the most optimistic of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)[8] scenarios, economically critical nature services will continue to decline in the future.

[1] The Convention on Biological Diversity (1992). Article 2. Use of Terms.

[2] IPBES (2021). Nature – Definition.

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

[4] Wurz, A., et al. (2021). Hand pollination of global crops–A systematic review. Basic and Applied Ecology 56: 299-321.

[5] NGFS (2022). Central banking and supervision in the biosphere: An agenda for action on biodiversity loss, financial risk and system stability.

[6] Global Futures (2020). Assessing the global economic impacts of environmental change to support policymaking. Summary report for government and business decision-makers.

[7] Each of the nine planetary boundaries represents a critical process for maintaining the stability and resilience of Earth system, with a critical limit not to be crossed. The remaining three boundaries are stratospheric ozone depletion, atmospheric aerosol loading and ocean acidification. Richardson et al. (2023). Earth beyond six of nine planetary boundaries.

[8] The IPBES is an intergovernmental body established to strengthen the science-policy interface for biodiversity and ecosystem services.

LINKAGES WITH SOVEREIGN BONDS

Nature degradation and biodiversity loss could impact the valuations of sovereign bonds. The three largest nature-dependent sectors produce close to $8 trillion of gross value added: construction (US$4 trillion of gross value added), agriculture (US$2.5 trillion), and food and beverages (US$1.4 trillion).[9] Together, these sectors are more than two times larger than the United Kingdom's economy in 2024.[10] Risks, however, are not limited to primary industries. Mining and metals, aviation, travel and tourism and real estate (for example) are highly dependent on nature and even more so through their supply chains.

Decreases in production capacity and increased vulnerability to natural disasters will negatively impact economic activity, resulting in changes in current account balances, exchange rates, debt profiles and tax revenues. Yet in many cases, these risks are still ignored or mispriced in bond markets.[11]

In contrast, countries that actively work to halt or reverse the loss of nature could see their creditworthiness improved as natural assets become scarcer and more valuable.[12] Ultimately, they might benefit from improved market access, increased capital inflows and better financing terms, providing them with better ability to repay their debt.

This is especially important for less developed countries and small or island states,[13] with natural capital constituting more than one quarter of wealth in lower- to middle-income countries and nearly half in low-income countries.[14] Nature plays a particularly critical role for the livelihoods of many low-income households. For instance, more than 90 percent of people living in extreme poverty rely on forests to sustain themselves.[15] A degradation of ecosystem services leading to GDP contractions could jeopardise global poverty-reduction and development efforts.

NATURE IN SUSTAINABLE FINANCE AND INVESTMENTS

Integrating nature-related considerations into financial assessments could offer more accurate measures of economic performance. Complete natural capital assessment and reporting, including the identification of risks and opportunities, could also be conducive to better financial allocation.

The number of regulatory frameworks and international initiatives focused on nature and biodiversity is growing (see Figure 1); the adoption of the Kunming-Montreal Global Biodiversity Framework by 196 nations in December 2022 is a step in that direction. Europe has played a leading role, integrating nature into many regulatory initiatives, such as SFDR, CSRD and the Deforestation-Free Products Regulation.

In the context of increasing regulatory frameworks, investors are slowly beginning to include biodiversity in sustainable finance policies and in their investment strategies. Today, the risks and opportunities are often analysed using a combination of in-house methodologies and datasets from third-party providers. Others indirectly apply sector-specific policy exclusions, such as on palm oil and deforestation, or use negative screening to exclude constituents exposed to biodiversity-related controversies.

Current finance flows to nature-based solutions stand at approximately US$200 billion, which represents only a third of what is required to reach climate, biodiversity and land degradation targets by 2030.[16]

At the sovereign level, bonds hold a key position given the role of government policy-making and public-financing play in the transition to a sustainable economy. Otherwise, a small but increasing number of funds and bonds with specific biodiversity objectives exists, although these are still limited in the sovereign space.

According to the Principles for Responsible Investment (PRI), investors cite a variety of blockers. Amongst these is a lack of access to high quality, relevant and fit-for-purpose data, which makes evaluating fund or investment exposure

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

[10] In 2024, the United Kingdom's GDP is estimated at US$3.5 trillion. International Monetary Fund (2024). World Economic Outlook Database: April 2024 Edition.

[11] Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science, and Planet Tracker (2020). The sovereign transition to sustainability: Understanding the dependence of sovereign debt on nature – Summary.

[12] Finance for Biodiversity Initiative. (2022). Nature Loss and Sovereign Credit Rating.

[13] Planet Tracker (2022). Nature Dependent Exporters: What do they have in common?

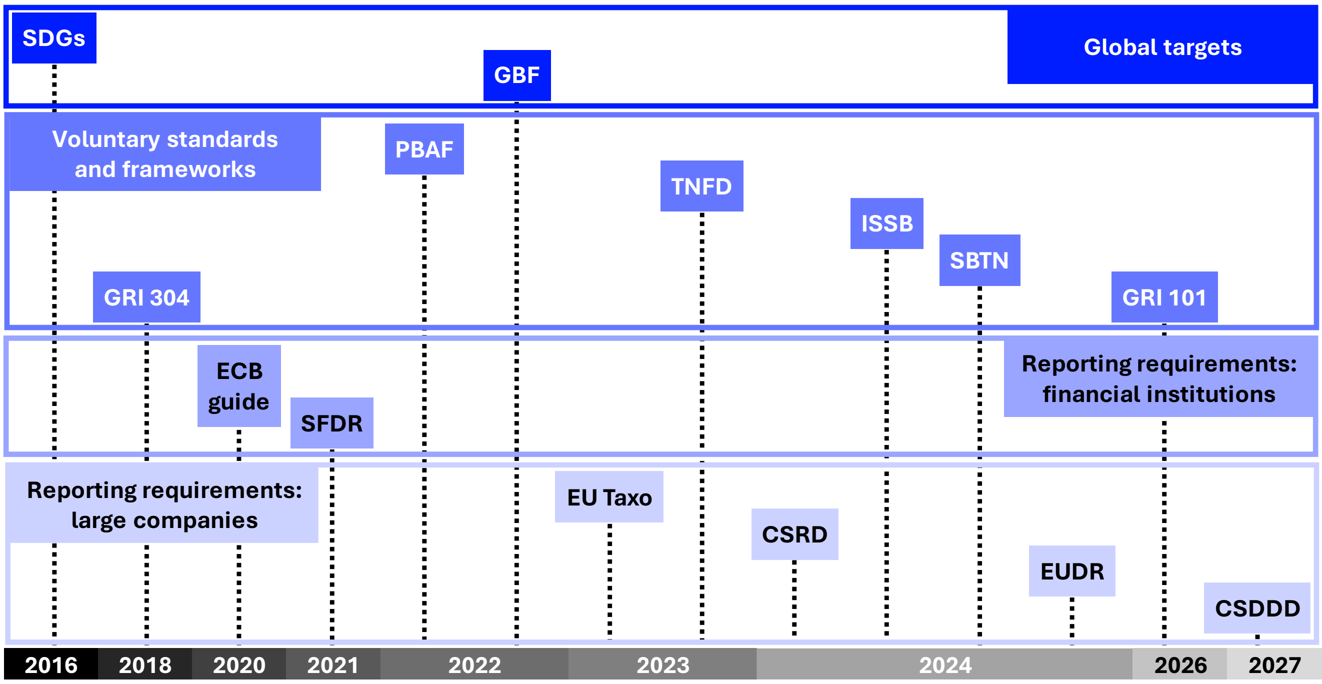
[14] Ninety One & WWF (2020). Climate & Nature Sovereign Index.

[15] World Bank (2021). The Economic Case for Nature: A Global Earth-Economy Model to Assess Development Policy Pathways.

[16] United Nations Environment Programme (2022). State of Finance for Nature. Time to act: Doubling investment by 2025 and eliminating nature-negative finance flows.

and impact challenging. Moreover, given that biodiversity risks and opportunities are mainly location-specific and must be analysed at the asset level, aggregating biodiversity data at the level of countries is relatively novel.[17]

Figure 1. The voluntary and regulatory nature-related reporting landscape



Global targets: ***SDGs****: Sustainable Development Goals;* ***GBF****: Global Biodiversity Framework.*

Voluntary standards and frameworks: ***GRI****: Global Reporting Initiative;* ***PBAF****: Partnership for Biodiversity Accounting Financials;* ***TNFD****: Taskforce on Nature-related Financial Disclosures;* ***ISSB****: International Sustainability Standard Board;* ***SBTN****: Science Based Targets Network.*

Reporting requirements for financial institutions: ***ECB****: European Central Bank Guide on climate-related and environmental risks;* ***SFDR****: Sustainable Financial Disclosure Regulation.*

Reporting requirements for large companies: ***EU Taxo****: EU taxonomy environmental objectives;* ***CSRD****: Corporate Sustainability Reporting Directive;* ***EUDR****: EU Deforestation Regulation;* ***CSDDD****: Corporate Sustainability Due Diligence Directive.*

Source: LSEG Sustainable Finance and Investment Research

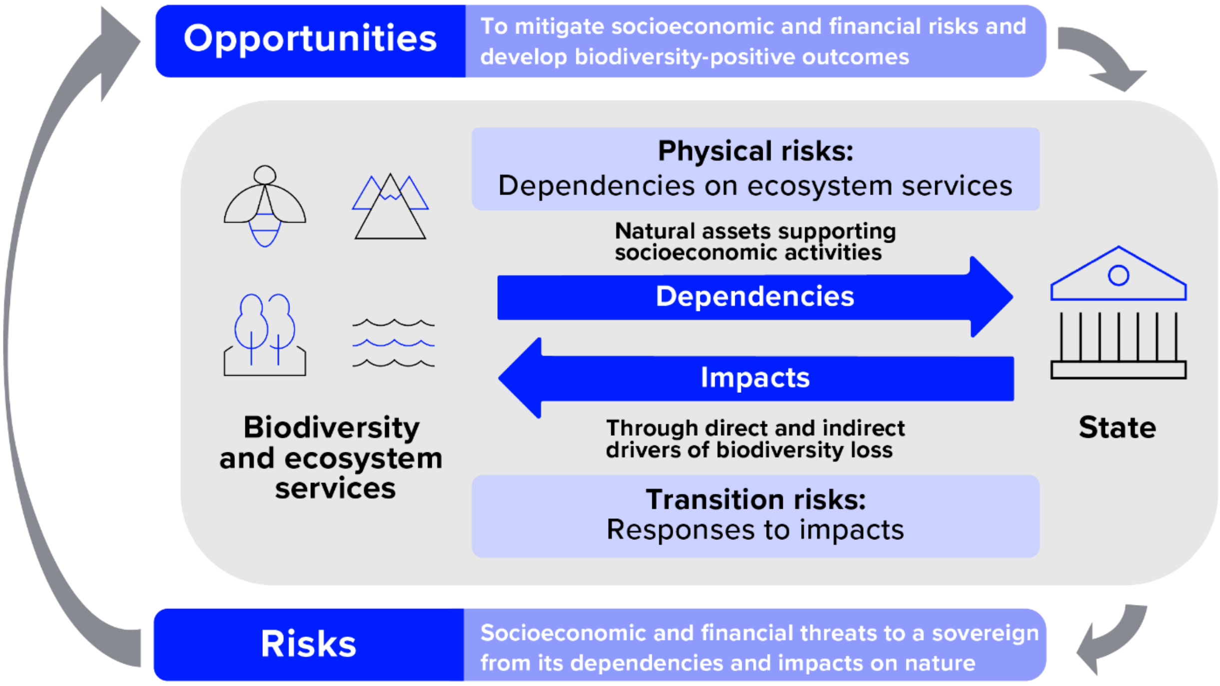
[17] UNPRI (2020). Investor Action on Biodiversity: Discussion Paper.

A summary of nature and biodiversity related datasets for sovereign analysis

Nature-related assessments can rarely be encapsulated in one single metric, and usually rely on a set of indicators to cover a range of aspects. One of the main challenges in integrating nature into sovereign investing, is to define which dimensions to cover, knowing that prioritising one over another can result in the loss of key information.

The development of new standards and frameworks, such as the one developed by the TNFD, can help to provide greater coherence. Although current applications still focus mostly on corporate assets, the same definitions can be broadly adopted for assessing sovereigns (see Figure 2).

Figure 2. Conceptual framework for nature-related risk assessments adapted to sovereign entities, revolving around dependencies, impacts, risks and opportunities.



Source: LSEG Sustainable Finance and Investment Research

In this section, we provide examples of relevant data and indicators for sovereign nature assessment, illustrative of the multidimensionality of such analysis. Table 1 presents the data selection and different classification systems, with the data sources detailed in Appendix 1. Use cases are also provided to highlight how the choice of data affects the results, particularly when looking at relative performance such as country rankings.

The selected indicators either directly reflect observed or modelled natural variables (e.g. land use or species) averaged at country level, or expose indirect interactions with nature through impact or dependency proxies (e.g., GDP dependency on nature). All these metrics, as a set, provide an overview of some nature-related challenges that countries will likely have to face.

Table 1. Example of classifications for the data selection presented in the paper

Indicators	TNFD Locate, Evaluate: interactions with nature	TNFD Assess: risk categories	Section	Page
Biodiversity intactness index	Sensitivity of a location	Physical (chronic, degradation) Transition (policy)	A	10
Threatened species	Sensitivity of a location	Transition (reputation, policy)	A	12
Critical habitats	Sensitivity of a location	Physical (chronic, loss of key areas) Transition (policy)	A	13
Protected areas	Sensitivity of a location	Transition (reputation, policy)	A	13
Land use / land cover	Impact (land use change) Dependency (provisioning, regulating services)	Transition (reputation, policy) Physical (chronic, loss of key areas, degradation)	B	14
Water resources	Dependency (provisioning services) Impact (resource exploitation)	Physical (chronic, increasing scarcity) Transition (reputation, market)	B	15
Light pollution	Impact (pollution)	Transition (policy)	Appendix 2	28
Pesticide use	Impact (pollution)	Transition (reputation, policy, market)	B	17
Invasive species	Impact (introduction of invasive species)	Physical (acute, amplified incidents)	B	17
GDP-related impact score	Impact (aggregation)	Transition (reputation, policy, market)	C	18
GDP-related dependency score	Dependency (aggregation)	Physical (chronic, acute, degradation, amplified incidents)	C	19

***TNFD-LEAP alignment**: Approach based on four phases of assessment; **Locate** the interface with nature; **Evaluate** dependencies and impacts on nature; **Assess** nature-related risks and opportunities; **Prepare** to respond to nature-related risks and opportunities.*

***Type of interaction with nature**: Approach based on (i) **Sensitivity** of a location to identify the areas of high biodiversity importance; (ii) **Dependency** to understand the services provided by nature useful to our society; (iii) **Impact** to explicit the role of human activities on nature's deterioration following the IPBES categories.*

***Risk category**: Approach based on climate-risk categories; **Physical** risks can be acute or chronic; **Transition** risks include policy, market, technology, and reputation.*

Applying with the Locate and Evaluate steps of the TNFD LEAP approach,[18] these metrics can be usefully grouped into three categories to look at the interface and types of interactions with nature:

– A first set of indicators measures the **sensitivity** of natural ecosystems at country-level. Some focus more on species, while others describe the state of habitats and ecosystems (see section A).

[18] The LEAP (Locate, Evaluate, Assess and Prepare) process is an integrated assessment approach designed by the TNFD to help organisations identify, assess, manage and disclose nature-related issues. TNFD (2023). Guidance on the identification and assessment of nature-related issues: The LEAP approach. Version 1.1.

– A second set of indicators attempts to capture **nature impacts or dependencies** at country-level. Impact categories are linked to the main drivers of biodiversity loss, as identified by the IPBES,[19] and include information such as changes in land use or in the availability and use of natural resources (see section B). Dependencies examine how countries rely on ecosystem services and are affected by changes in natural capital.

– A final set of metrics also measures impacts and dependencies but goes further by trying to quantify them in economic terms. In other words, they provide a measure of the exposure of economic activities to material nature-related impacts and dependencies, using GDP as a proxy (see section C).

For the Assess step of LEAP, nature-related impacts and dependencies translate into financial risks and opportunities. Analogous to climate assessments, nature-related risks can be categorised as transition or physical risks (see Table 1).

– Most of the indicators can be used to assess the **transition** efforts that a country will have to implement to reduce its negative impacts and protect sensitive areas. These efforts can take multiple forms, such as investments or new regulations.

– Other indicators underline the **physical** challenges to be tackled to ensure the long-term capability of a country to benefit from ecosystem services provided by nature.

A. WHAT INDICATORS ARE USEFUL FOR ASSESSING THE SENSITIVITY OF NATURE AT COUNTRY-LEVEL?

Biodiversity and living species are the key components of nature. Understanding the state of living diversity and the threats looming over key species on one hand, and the species' habitats condition on the other, is crucial to assessing the fragility of ecosystems providing critical services to national economies.

Biodiversity Intactness Index (BII)

Rationale: The BII assesses the state of biodiversity, on a scale from pristine to annihilation, compared to a reference state taken at the industrial revolution. It provides information on the capacity of a country to provide ecosystem services, or its incapacity if too many areas are close to a completely deteriorated zone.

Source: Natural History Museum

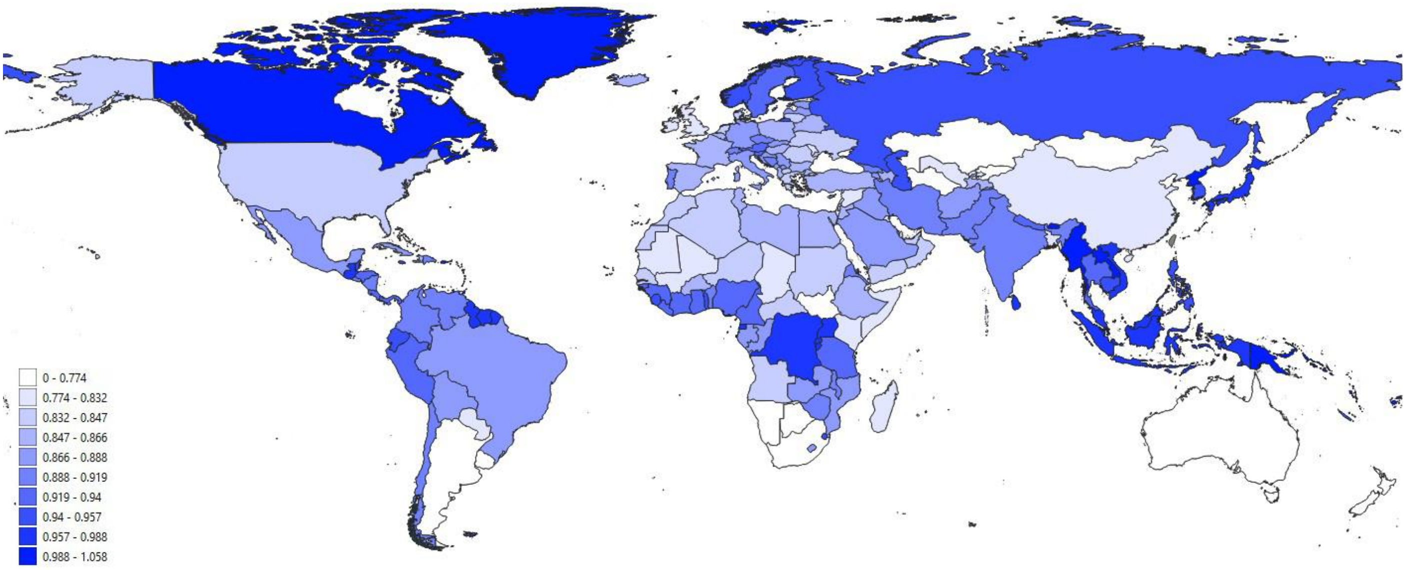
Outputs: Different metrics can be derived from it; an average view of the situation (average or median) highlighting the level of damage inside the country, a measure of the range of damage inside the country (standard deviation) or the best/worst case by country (minimum/maximum, respectively).

Caveat: It is worth mentioning that, despite using the same data, the different metrics described above measure different aspects and will lead to different rankings (see example in Figure 3).

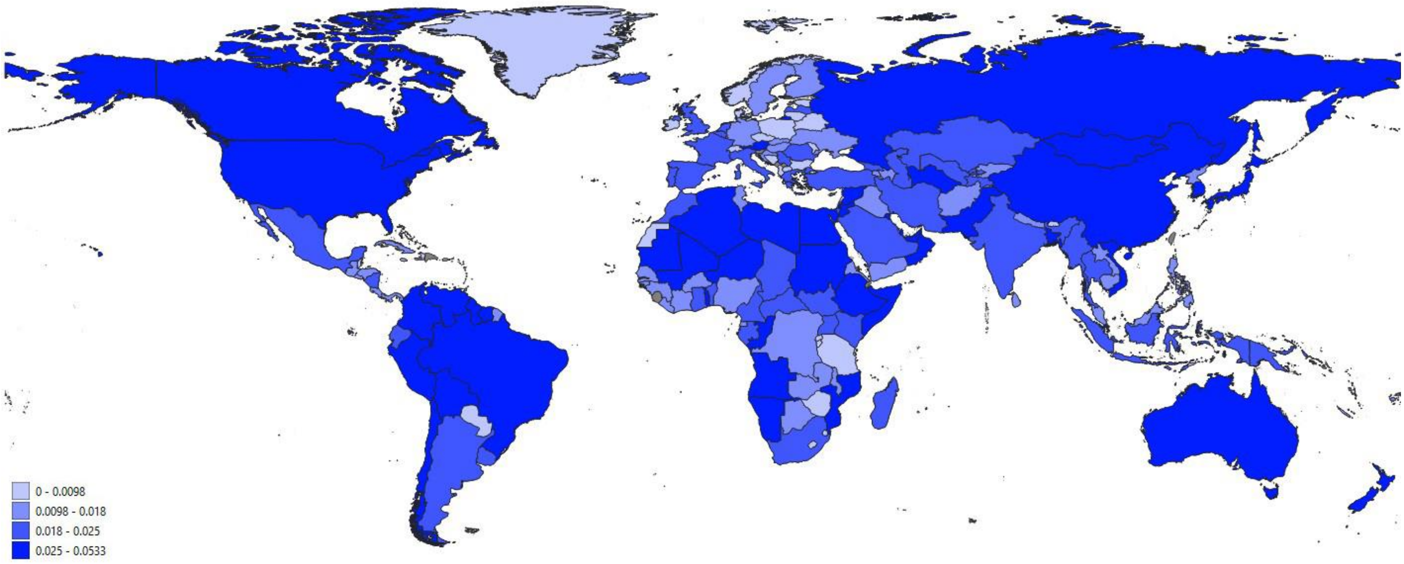
[19] The IPBES has identified five main drivers of biodiversity loss: land- and sea-use change, overexploitation of organisms, climate change, pollution, and invasive alien species.

Figure 3. Measures of BII per country

a- Mean BII in each country



b- Standard deviation of the BII inside each country



Source: AXA Climate

Threatened species

Rationale: Threatened species signal a broader deterioration of ecosystems, increasing the probability that the country will act. This metric reflects a transition risk, such as the development of restoration and conservation strategies, or the launch of new policies.

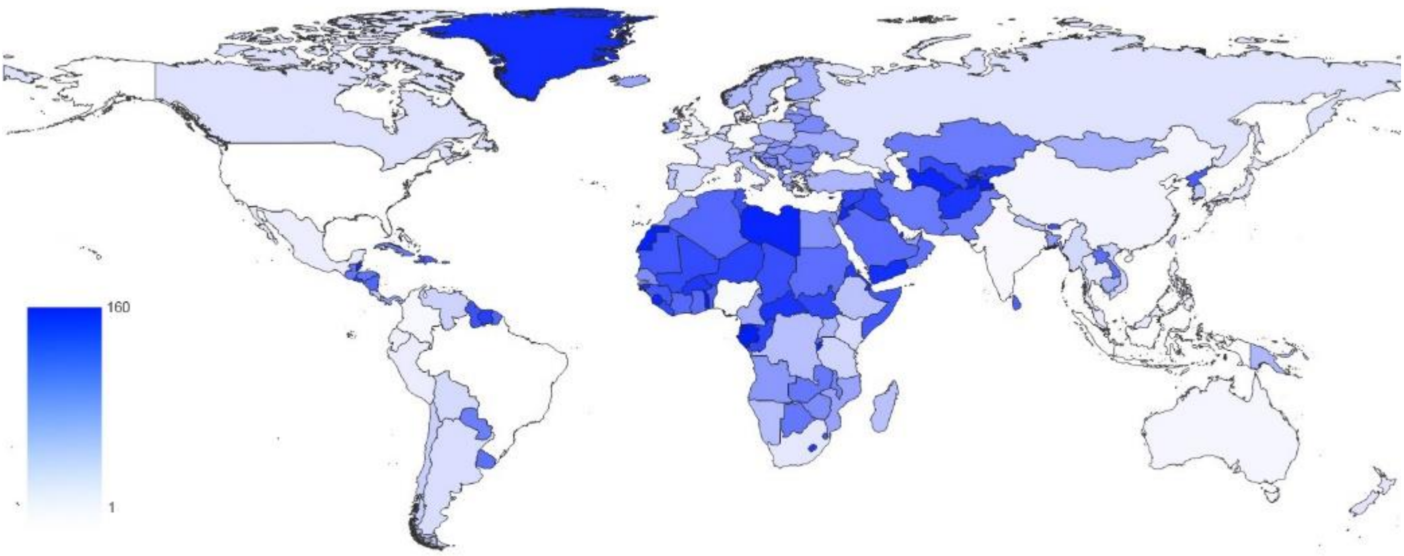
Sources: GBIF (Global Biodiversity Information Facility) and IUCN Red List.

Outputs: The level of species threatened in a country can be pictured by taking the most sampled classes, such as mammals or birds, with a level of threat. However, the results differ depending on what is accounted for: considering the raw number of threatened species per country (Figure 4), relating this number to the area of the country (b) or to the total number of species of the country (c) can change relative rankings. For instance, large countries tend to be favoured by the second option.

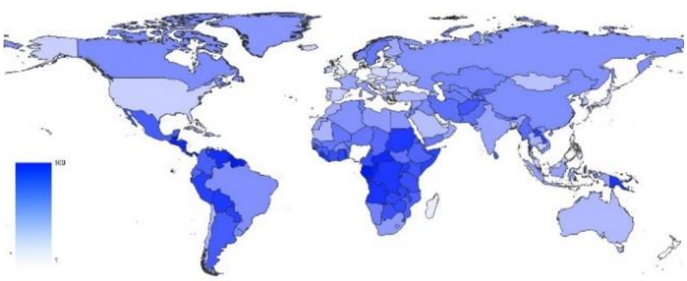
Caveat: These data are incomplete and highly biased, as they mostly come from incidental sampling (e.g. direct observations or data collection from scientific publications). Some licences also limit their availability for investors.

Figure 4. Different calculations of the diversity of threatened bird (Aves class) species per country based on GBIF species listing

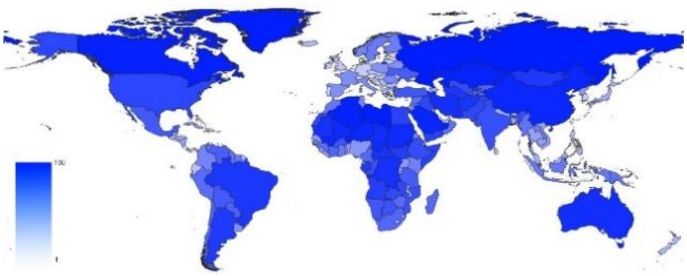
a- Ranking of the countries based on the number of threatened species[20]



b- Ranking of countries based on the ratio of threatened species/total species



c- Ranking of countries based on the number of threatened species per km²



Source: AXA Climate

[20] The country ranked 1 has the highest number of threatened species; the 160th has the lowest number.

Critical habitats

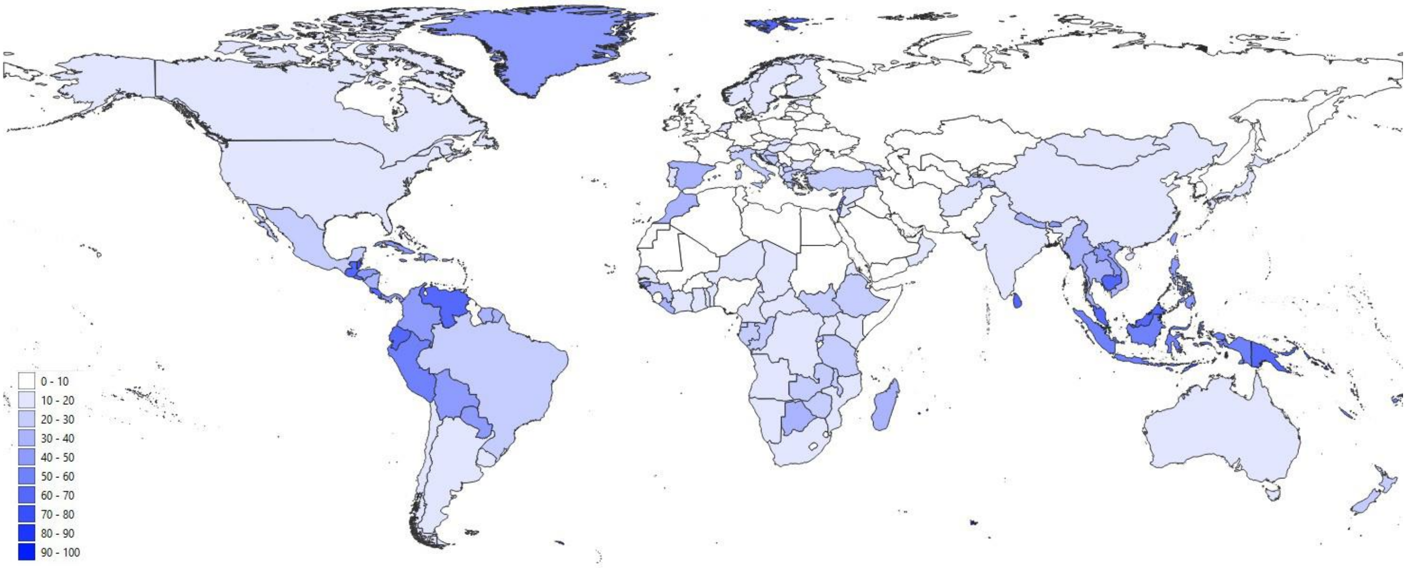
Rationale: Critical habitats are defined by the International Finance Corporation (2012)[21] as 'areas with high biodiversity value' in terms of species, habitats, ecosystems and even evolutionary processes. These habitats contribute to biodiversity and the resulting ecosystem services. As such, understanding their locations provides insights for the study of some dependencies.

Source: UNEP-WCMC

Outputs: Three categories are used to segment the world: unclassified (not a critical habitat), potential and likely critical habitat. It is then possible to compute the percentage of critical habitats per country by looking at the surface identified as potential or likely critical. This indicator highlights the key importance for biodiversity of some countries in South America and Southeast Asia (as shown in Figure 5).

Caveat: There is no distinction made between the potential and likely critical habitats in this indicator. Moreover, ecosystem services are also provided by non-critical habitats and as such this information must be completed with other indicators.

Figure 5. Percentage of critical habitats per country



Source: AXA Climate

Protected areas

Rationale: Protected areas can be used to assess the trajectory of a country towards nature preservation. They reflect its alignment to the Kunming-Montreal Global Biodiversity Framework (target of 30% of protected areas) and its willingness to maintain ecosystems and preserve habitats from anthropic pressures.

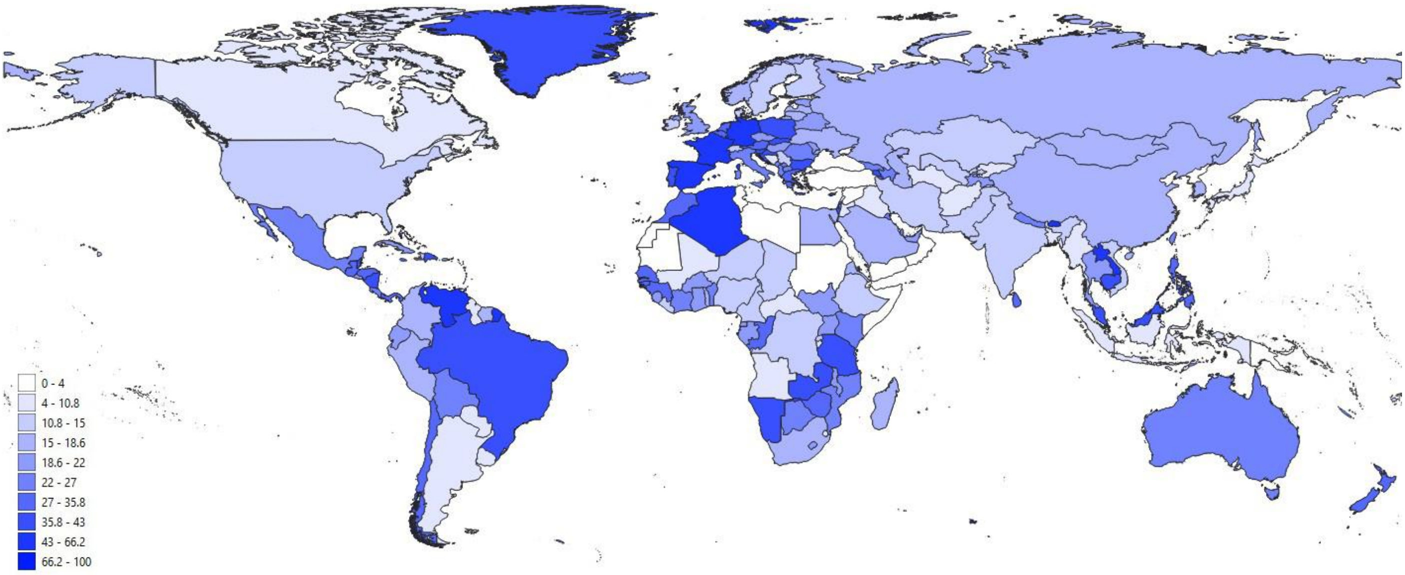
Source: AXA Climate

Outputs: Human legislation for nature protection can be quantified through the percentage of protected areas – defined as the proportion of total geographic areas with sufficient wildlife protection regulations. Figure 6 shows an important diversity of protection levels across sites and countries. Europe appears to perform relatively well compared to other regions.

Caveat: It is very complex to aggregate and clean a global dataset, as there are many different categories of protected areas, with different protection standards. Thus, comparing countries or the proximity of a country with the 30% target may require expert re-analysis.

[21] International Finance Corporation (2012). Performance Standard 6, Biodiversity Conservation and Sustainable Management of Living Natural Resources.

Figure 6. Percentage of protected areas per country



Source: AXA Climate

B. WHAT INDICATORS ARE USEFUL FOR ASSESSING THE COUNTRY-LEVEL MATERIAL IMPACTS ON AND DEPENDENCIES TO NATURE?

Beyond the direct impacts on living organisms and their habitats, human activities also impose indirect threats on nature through changes to resources availability. Assessing these changes is also important to understanding how nature capital has been and could be impacted in the future, as well as potential effects on human populations and activities.

By understanding the level of modification (e.g. invasive species) or deterioration of nature at country level (e.g. deforestation), it is possible to study the transition risks faced by a country as well as the physical challenges faced by the loss of natural resources.

Land use and land cover (LULC)

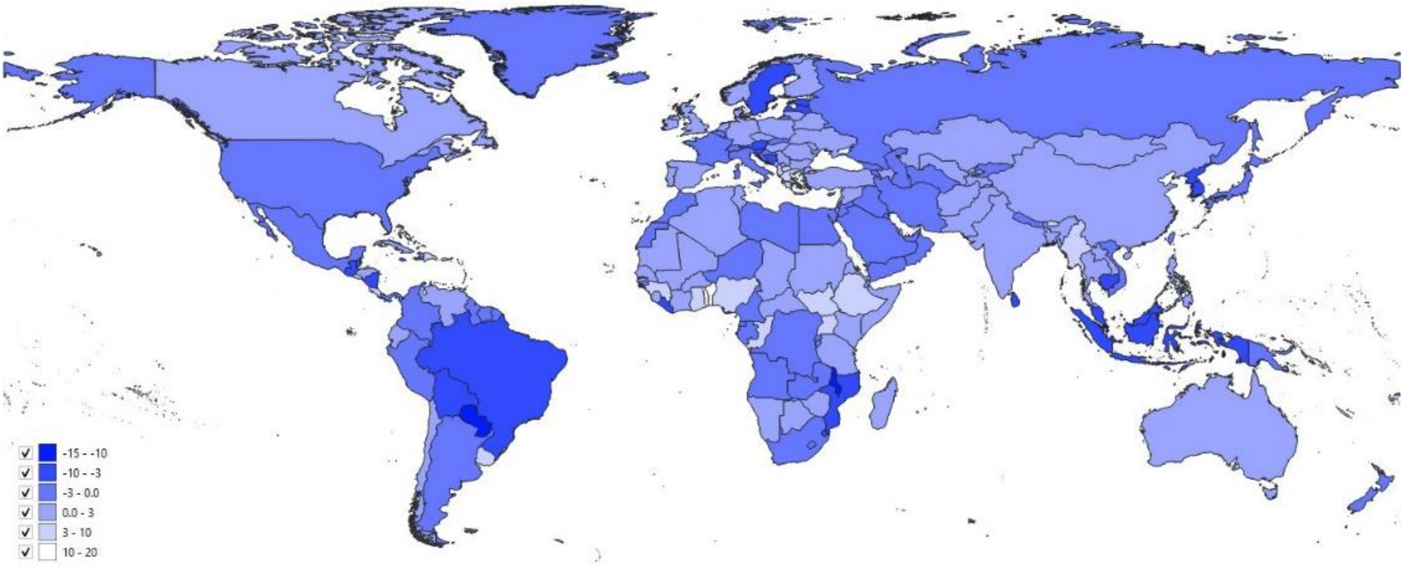
Rationale: LULC can show a point in time picture of nature but also its evolution. It is a good indicator for estimating the IPBES pressure called land-use change. For instance, by looking at the evolution of forest cover (as shown in Figure 7), it is possible to estimate the necessity for a country to act on its deforestation risk.

Source: ESA WorldCover

Outputs: Based on the classification of the LULC over time, it is possible to observe the evolution of categories such as forests, agricultural zones, or urban areas per country. The results provide an indication of a country's impact (positive or negative) on nature through the restoration or loss and fragmentation of habitats.

Caveat: For some indicators, the trends can change dramatically depending on the observation period. Moreover, the sources may have different resolutions and classification systems, resulting in different outcomes (for instance, see the comparison with the NASA MODIS dataset in Appendix 2).

Figure 7. Percentage of deforestation (1992-2022) per country[22]



Source: AXA Climate

Water resources

Rationale: Water is key for all species (including humans) and ecosystems to thrive. A lack of water thus represents a significant physical risk and transition risk and is often assessed through water stress: the total water demand by human societies versus catchment-level water supply by ecosystem services.[23] Nonetheless, other indicators like seasonal variability, droughts, or water quality can also be relevant.

Source: Aqueduct 4.0 by the World Resources Institute

Outputs: A sovereign-level indicator and ranking accounting for the demand by sectors (agricultural, industrial and domestic) can be computed, and would be available for three IPCC scenarios and timeframes.

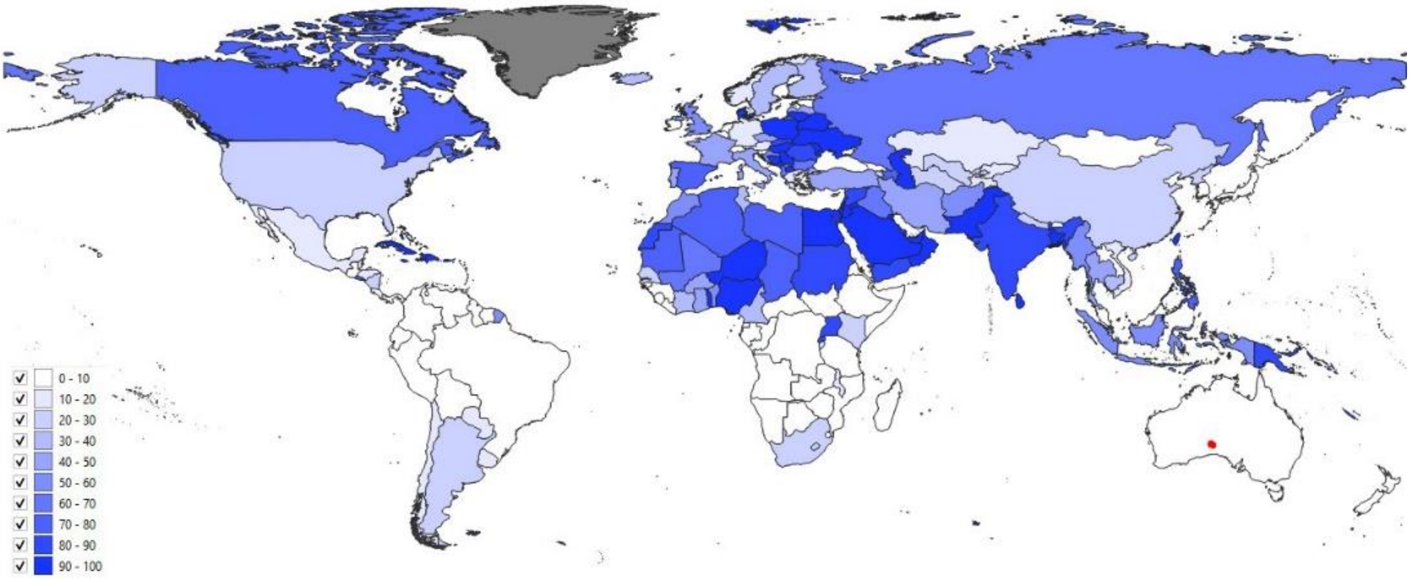
Caveat: Using metrics that appear similar, such as water stress and drought risk can lead to very different results, as highlighted in Figure 8. Thus, country rankings cannot be directly compared, although both factors importantly impact ecosystems.

[22] A negative percentage of deforestation indicates a net loss of forest, while a positive percentage indicates a net gain.

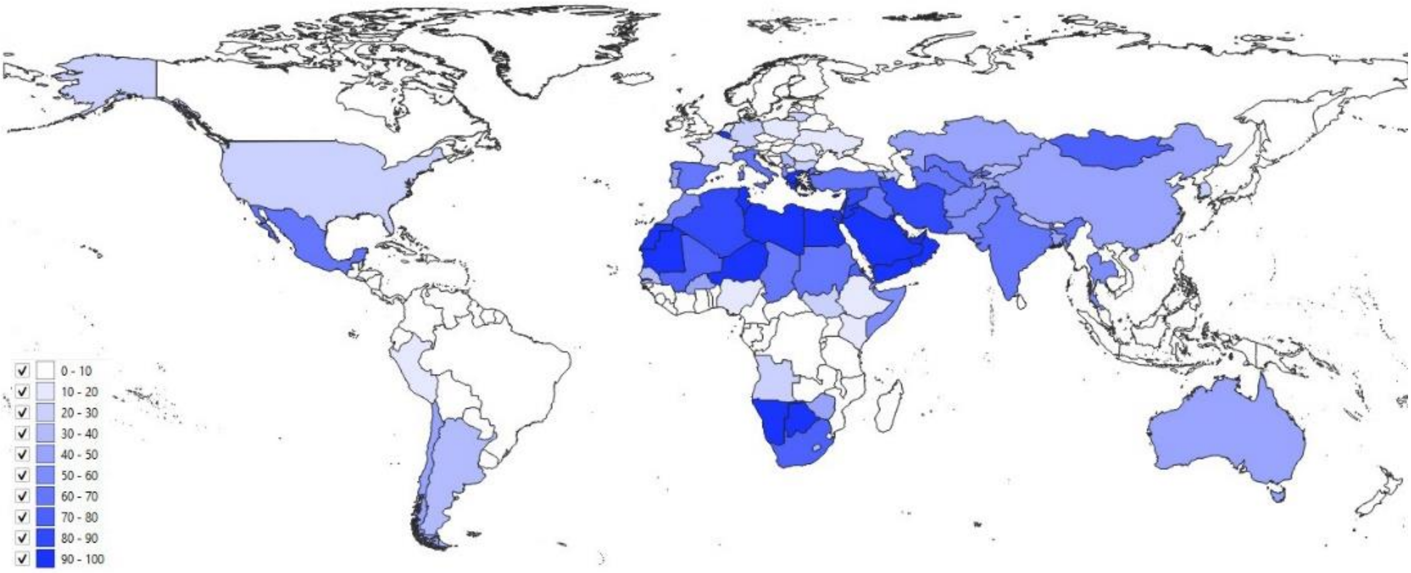
[23] A catchment may be defined as any area of land where the water collects and drains to a common outlet, such as river, lake or coastal waterbody.

Figure 8. Two different water-related indicators

a- Drought risk



b- Water stress



Source: AXA Climate

Pesticide use

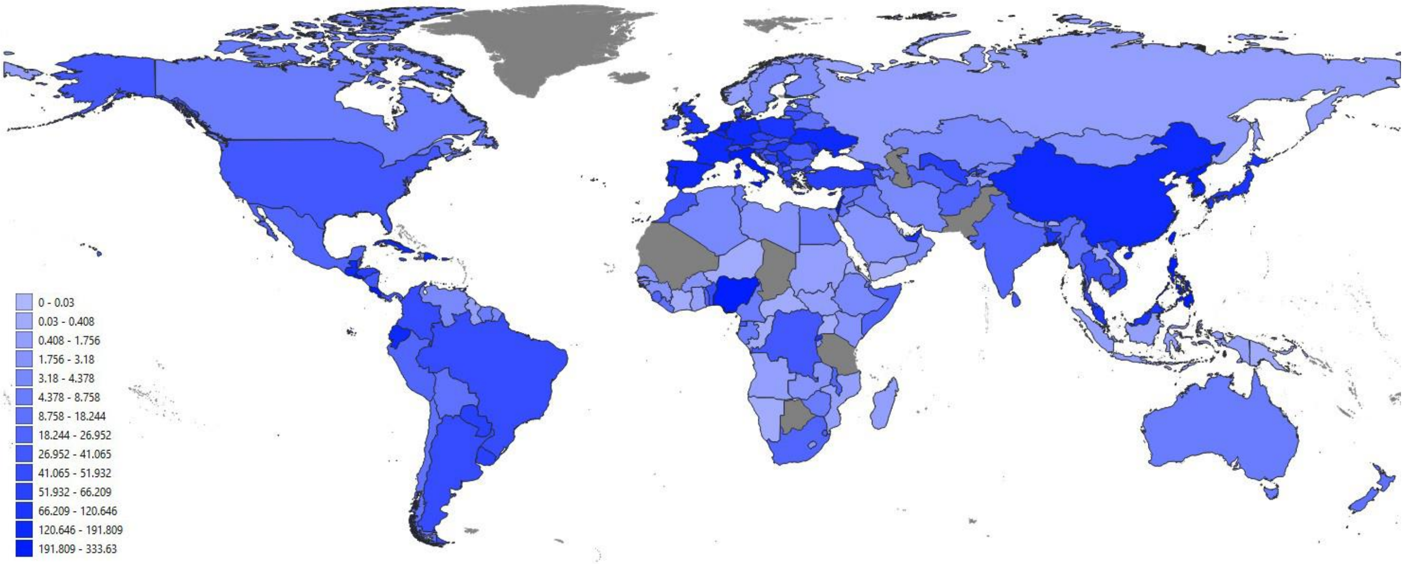
Rationale: Pesticides have direct and indirect impacts on ecosystems. They contribute to the decline of numerous species, including pollinators, which causes pest resurgence and disruption of the food chain, ultimately leading to major alterations or interruptions of ecosystem services. The quantity of pesticides used in a country significantly informs the transition risk relative to the IPBES pressure of pollution, notably in the agriculture sector.

Source: PEST-CHEMGRIDS

Outputs: From the PEST-CHEMGRIDS database, it is possible to estimate in each country and for the most common crops, the amount of the most used pesticide present per unit of surface (Figure 9). This yields a meaningful indicator for pesticide pollution.

Caveat: This dataset lacks exhaustivity: it only accounts for the main crops and pesticides. In addition, application rates are estimated rather than measured.

Figure 9. Estimation of pesticide mass [kg] per km²



Source: AXA Climate

Invasive species

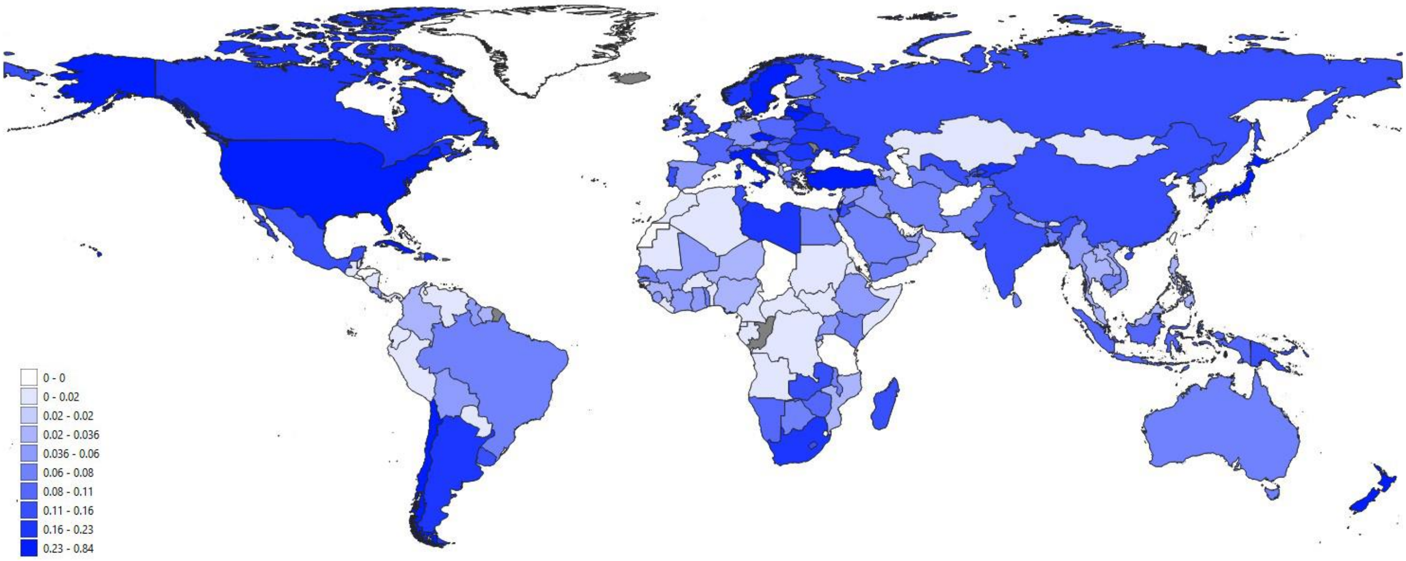
Rationale: Invasive species have been identified as one of the five main threats to biodiversity by the IPBES. They alter existing food chains and habitats, which can lead to biodiversity loss and ecosystem collapse.

Sources: Global Register of Introduced and Invasive Species (GRIIS) and Global Biodiversity Information Facility (GBIF)

Outputs: Using GRIIS and GBIF databases, this risk can be proxied by looking at the percentage of invasive species with respect to the total number of species in the country (see Figure 10).

Caveat: Species data are biased as they are mostly based on incidental sampling (e.g. direct observations or data collection from scientific publications). Restrictive licenses for GRIIS and some of GBIF observations limit their availability for investors.

Figure 10. Percentage of invasive species per country



Source: AXA Climate

C. HOW CAN WE ASSESS THE ECONOMIC IMPACTS ON NATURE, OR DEPENDENCIES TO NATURE, OF A COUNTRY?

Understanding how much a country's economy relies on potentially harmful sectors, can provide a proxy for the potential impacts of economic activity on nature at country-level.

Conversely, assessing how much a country's economy relies directly on services provided by nature, it is possible to understand how critical nature is for the country and how severe the consequences of its continuing deterioration would be.

Aggregated impact score of GDP

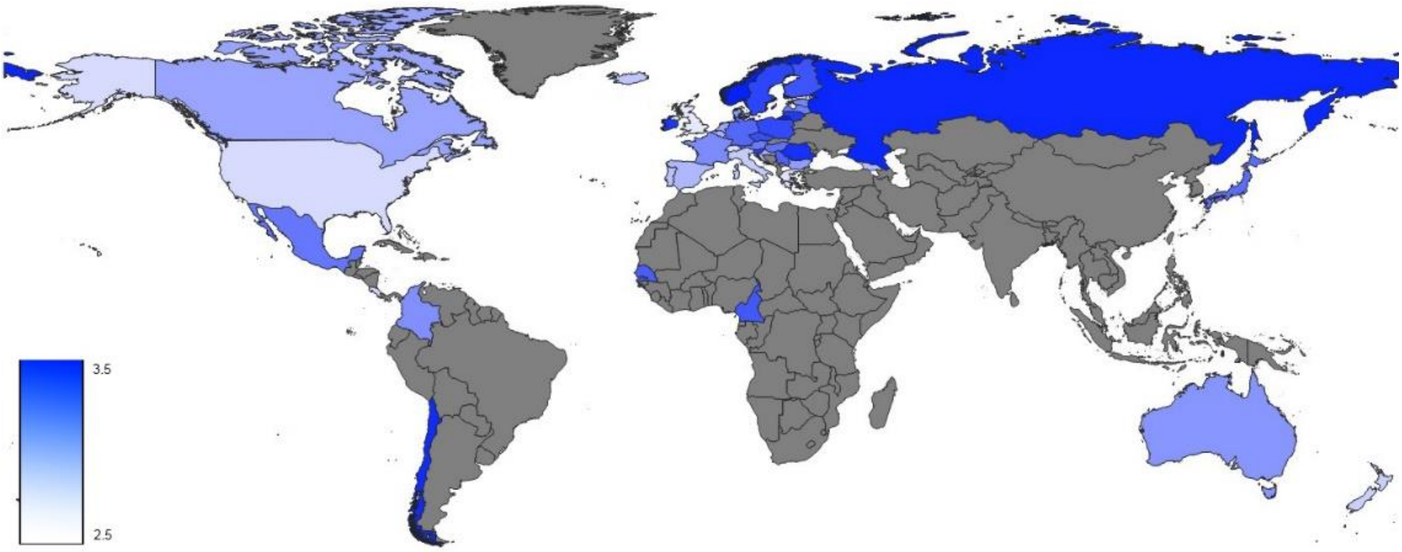
Rationale: Observing the impacts of a country on biodiversity goes beyond spatial analysis, as these depend highly on its sectors of activity. Using GDP as a proxy for the weight of each activity in the economy, it is thus possible to study the magnitude of its transition risk.

Source: SBTN Sectoral Materiality Tool for Step 1a

Outputs: From the SBTN Tool, it is possible to calculate an aggregated average impact score for each of the 21 major sections of the ISIC Rev 4 classification and a detailed impact score for each of the five IPBES pressures (Table 3 in Appendix 3 provides an example). For instance, regarding the 'resource exploitation' pressure, countries with significant mining and quarrying activities present higher impact scores on the resource dimension (see Figure 11).

Caveat: By using mean impacts of each sector, the indicator does not consider the efforts already carried out by a country or individual specificities that reduce impacts on nature. Moreover, the methodology relies on the availability of countries' GDP breakdown by sector of activity, which makes it more difficult to apply at a global scale.

Figure 11. Impact score for the resource exploitation category for 48 countries



Source: AXA Climate

Aggregated dependency score of GDP

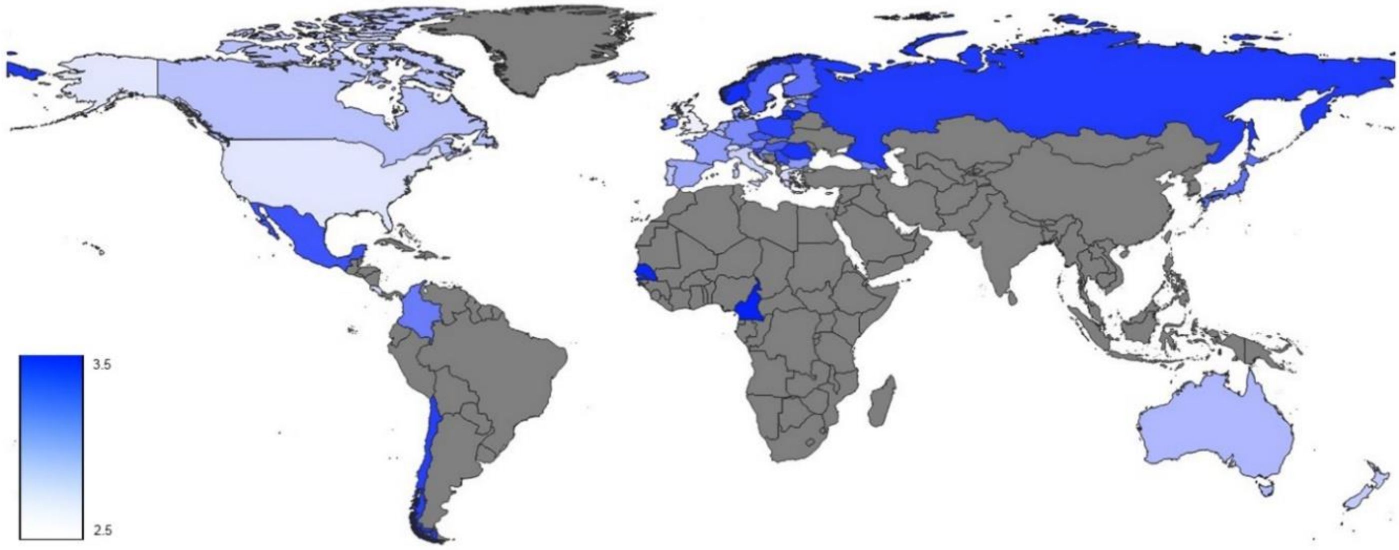
Rationale: As for their impacts, dependencies of a country on biodiversity go beyond spatial analysis and are linked to its sectors of activity. The evaluation of a country's dependency on nature and the magnitude of its transition risk can be assessed using GDP as a proxy for the weight of each sector of activity.

Source: ENCORE

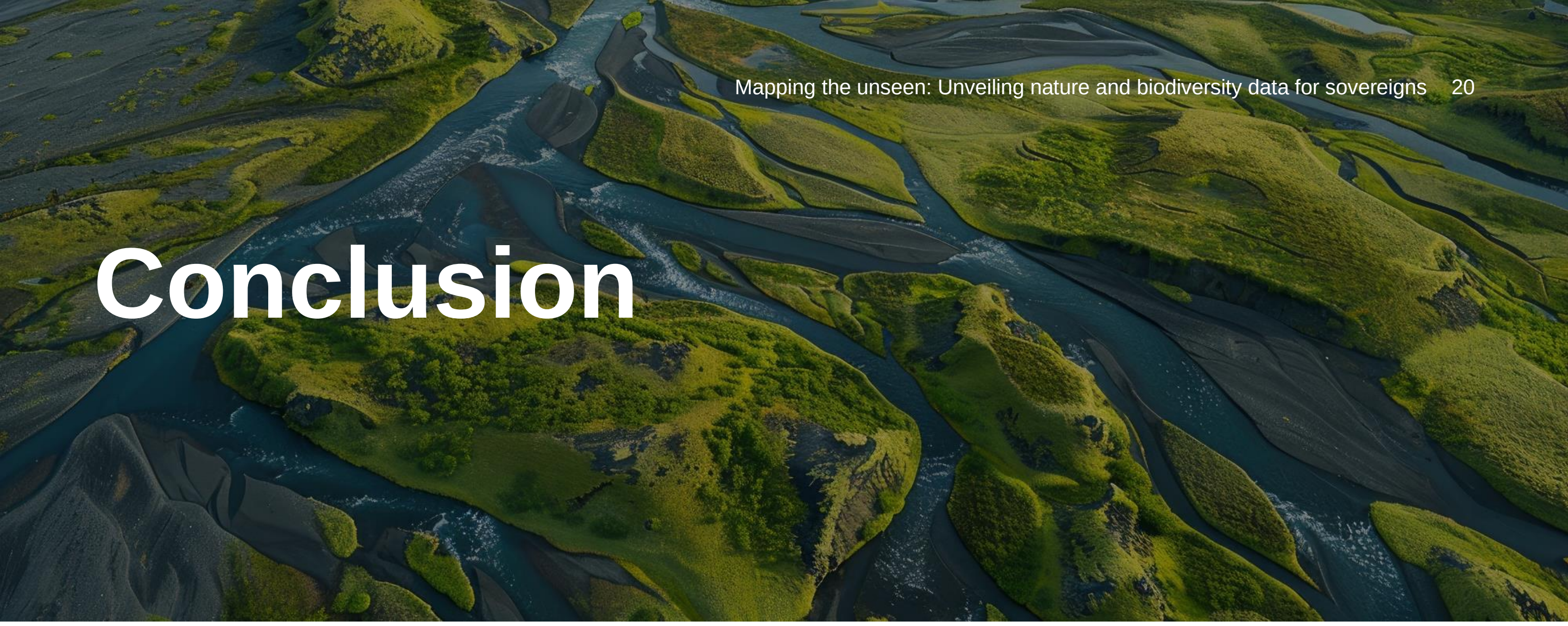
Outputs: From the ENCORE database, it is possible to calculate an average dependence score for each of the 21 major sections of the ISIC Rev 4 classification based on the dependency on every ecosystem service it relies on.

Caveat: By using mean dependencies of each sector, the indicator does not consider the efforts already carried out by a country or individual specificities that reduce its dependencies on nature. Moreover, the methodology relies on the availability of countries' GDP breakdown by sector of activity, which makes it more difficult to apply at a global scale.

Figure 12. Dependency score for 48 countries



Source: AXA Climate



Conclusion

This report shows that nature-related indicators that can be applied in the sovereign context come from a wide variety of sources, ranging from NGOs to research centres or think tanks.[24]

The emergence of spatial and remote sensing-based sustainability intelligence and the development of commercial or open-source portals, further increase the availability of nature-related datasets to investors. For instance, tools such as the WWF's Biodiversity and Water Risk Filters are now freely available online for investors wishing to locate the interface of their debt exposures with nature.[25]

Nonetheless, the challenges related to the use of these datasets for sovereign nature risks assessment remain numerous (see Table 2).

Currently, the most common intended use of nature-related data is for **reporting and disclosure**. At the portfolio level, aggregated scores or disaggregated metrics can be calculated to measure how the portfolio performs with respect to a given benchmark, or to highlight the best- and worst-in-class constituents.

Countries can also be benchmarked for individual nature aspects (e.g. deforestation). This offers the potential to **assess their performance** with respect to national and global commitments or relative to other countries.

Finally, nature-related aspects could also be considered in **portfolio construction or indices**, to better understand the investable universe according to nature risks or performance or to construct nature-adjusted versions of sovereign bonds indices.

As interest in and awareness of the importance of nature and biodiversity grow within the finance industry, selecting the relevant set of indicators for a specific use case is crucial. Misunderstanding or misusing data can impact decision making, and ultimately lower investors' confidence in nature and biodiversity assessments.

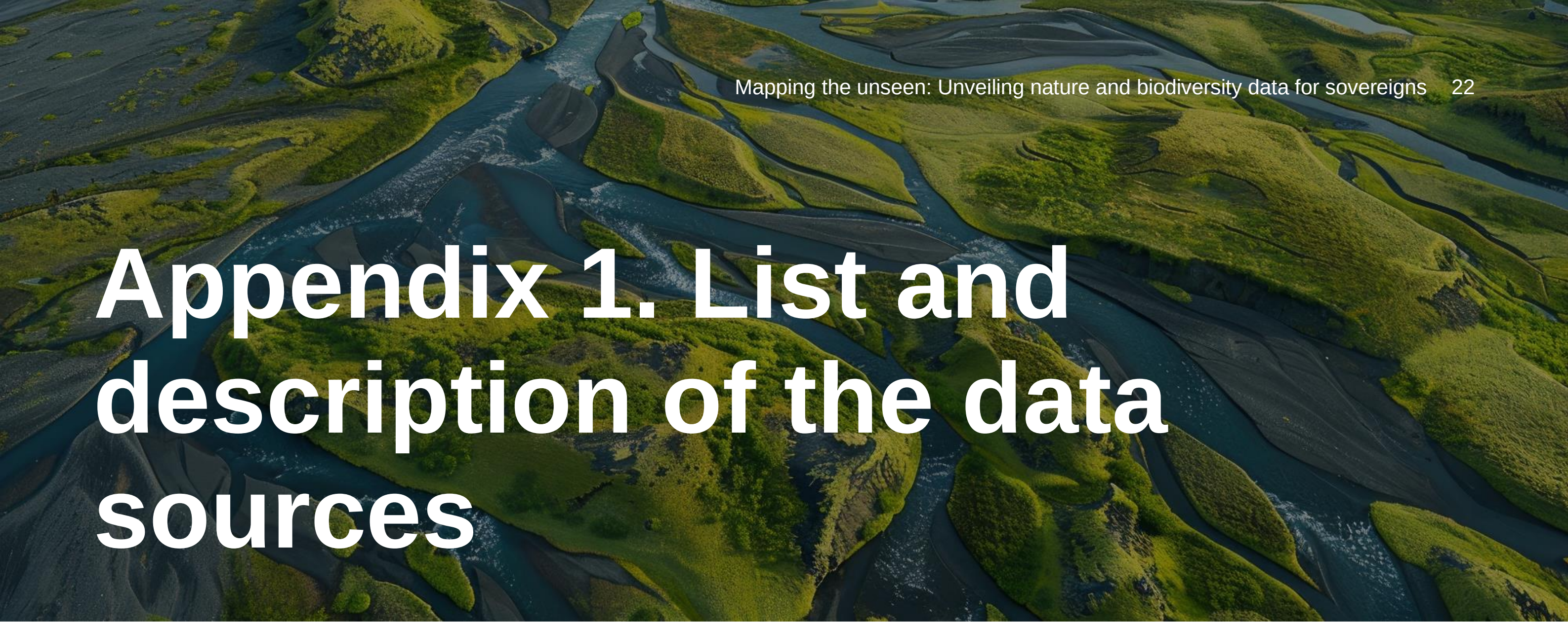
Enhanced collaboration between researchers and financial institutions is required to ensure an alignment of methodologies and data with their respective purpose. Further standardisation of the approaches, as described in recent guidance documents such as the TNFD, will also help increase the uptake of complex nature-related data and facilitate their use by non-specialists.

[24] OECD (2023). Assessing biodiversity-related financial risks: Navigating the landscape of existing approaches.
[25] World Wildlife Fund (2023). WWF Risk Filter Suite.

Table 2. Data challenges related to their use for sovereign nature risks assessment.

Spatial coverage	For nature-related assessments, economic assets must be geographically located. By identifying economic actors in the value-chain, dependencies and impacts can be accurately mapped to financial outcomes. The difficulty for sovereigns lies in aggregating nature-related risks that are inherently local at the country level.
Temporal coverage	Numerous datasets are generated as part of one-off studies or are updated irregularly. This may lead to consistency issues, especially when reporting is concerned, and complicates the assessment of nature-related indicators over time.
Non-exhaustivity	Data availability varies between countries, as is the case with corporate issuers. The quantity of data available can be limited across time and across geography, making sufficiently informed analyses complex. In addition, not all sovereigns have the capacity to disclose all nature-related material information.[26]
No one-size-fits-all approach	The inherent complexity of nature, its intricate components and ever-changing structure make it impossible to reduce to a single metric. Multiple datasets are necessary to capture the various spatial and ecological facets but, with the plethora of data available, it can be tricky to identify the right indicator for the right dimension.
Comparability	Nature and biodiversity metrics do not have standardised methodologies, which differ in inputs, assumptions, and modelling techniques. Users must be aware that the different metrics are not always comparable for analysis. It is thus important for practitioners to understand both the capabilities and limitations of each metric.
Complexity	Translating environmental data in a useful and understandable way is challenging. Each component requires tailored data and the tools available are not homogenous in quality. Consequently, a lack of usable metrics and insufficient internal expertise are cited as the main barriers to integrating biodiversity in investment strategies.[27, 28]

[26] Nature Finance (2023). Assessing Nature-Related Issues in Sovereign Debt Investment.
[27] Robeco (2023). Global Climate Survey: Are investors moving from aspiration to implementation?
[28] TNFD (2022). A landscape assessment of nature-related data and analytics availability. Discussion paper.



Appendix 1. List and description of the data sources

Aqueduct. 4.0 – Water-related risk quantities

Description	Based on PCR-GLOBWB-2 hydrological model,[29] it gives 13 water risk indicators in baseline and IPCC projections, including water supply and demand, water stress, drought risk, flood, etc.
Source	Kuzma, S., et al. (2023). Aqueduct 4.0: Updated decision-relevant global water risk indicators. World Resources Institute, 1-52. https://www.wri.org/research/aqueduct-40-updated-decision-relevant-global-water-risk-indicators
Year of publication	2023
Spatial resolution	Worldwide, HydroBASINS 6
Temporal resolution	Baseline (1979-2019) and projections (3 scenarios (SSP1-2.6, SSP3-7.0, SSP5-8.5) in 3 timeframes (2030, 2050, 2080))

Biodiversity Intactness Index (BII)

Description	It provides a statistical modelling of total organisms' abundance and compositional similarity reaction to land use and related pressures from the reference year 1970.[30, 31]
Source	Newbold, T., et al. (2016). Global map of the Biodiversity Intactness Index, from Newbold et al. (2016) Science [Data set]. Natural History Museum. DOI: https://doi.org/10.5519/0009936
Year of publication	2016
Spatial resolution	World-wide, 30arc sec
Temporal resolution	2005

[29] Sutanudjaja, E. H., et al. (2018). PCR-GLOBWB 2: a 5 arcmin global hydrological and water resources model. Geoscientific Model Development, 11(6), 2429-2453.
[30] Scholes, R. J., and Biggs, R. (2005). A biodiversity intactness index. Nature, 434(7029), 45-49.
[31] Phillips, H., et al. (2021). The Biodiversity Intactness Index - country, region and global-level summaries for the year 1970 to 2050 under various scenarios [Data set]. Natural History Museum.

Critical habitats

Description	Based on International Finance Corporation (IFC PS6), this is the worldwide distribution of critical habitats into three categories: unclassified, potential or likely critical.[32, 33]
Source	UNEP-WCMC (2017). Global Critical Habitat screening layer (Version 1.0). Cambridge (UK): UN Environment World Conservation Monitoring Centre. DOI: https://doi.org/10.34892/nc6d-0z73
Year of publication	2017
Spatial resolution	World-wide, 1km

ENCORE

Description	ENCORE (Exploring Natural Capital Opportunities, Risks and Exposure) is an assessment tool of impact and dependencies on nature for economic sectors, subsectors, and their production processes.
Source	ENCORE Partners (Global Canopy, UNEP FI, and UNEP-WCMC) (2024). ENCORE: Exploring Natural Capital Opportunities, Risks and Exposure. [On-line], [February 2021 version downloaded], Cambridge, UK: the ENCORE Partners. DOI: https://doi.org/10.34892/dz3x-y059
Year of publication	2018

ESA World Cover

Description	Land cover based on remote sensing data from Sentinel-1 and Sentinel-2 with 20 land cover classes: cropland; herbaceous cover; tree or shrub cover; mosaic cropland; mosaic natural vegetation; tree cover, broadleaved, deciduous, closed to open; tree cover, needle leaved, evergreen, closed to open; tree cover, needle leaved, deciduous, closed to open; tree cover, mixed leaf type; mosaic tree and shrub; mosaic herbaceous cover; shrubland; grassland; sparse vegetation; shrub or herbaceous cover, flooded, fresh/saline/brackish water; urban areas; bare areas; consolidated bare areas; unconsolidated bare areas; water bodies.
Source	Copernicus Climate Change Service, Climate Data Store, (2019): Land cover classification gridded maps from 1992 to present derived from satellite observation. Copernicus Climate Change Service (C3S) Climate Data Store (CDS). DOI: 10.24381/cds.006f2c9a
Year of publication	2022
Spatial resolution	World-wide, 10m
Temporal resolution	Yearly, 1992- 2020

[32] Martin, C. S., et al. (2015). A global map to aid the identification and screening of Critical Habitat for marine industries. Marine Policy 53: 45-53.
[33] Brauneder, K.M., et al. (2018). Global screening for Critical Habitat in the terrestrial realm. PloS one, 13(3), p.e0193102.

GBIF – Species observations

Description	GBIF (Global Biodiversity Information Facility) is an international structure gathering and aggregating species-related data, mainly species observations, through a large network of sources.[34]
Source	GBIF.org (2024). Free and open access to biodiversity data [On-line]. https://www.gbif.org/
Year of publication	2001
Spatial resolution	Geo-referenced observations
Temporal resolution	Dates of observation

GRIIS – Invasive species

Description	GRIIS (Global Register of Introduced and Invasive Species) is a checklist of alien invasive species by country.
Source	Pagad, S., et al. (2018). Introducing the Global Register of Introduced and Invasive Species. Sci Data 5, 170202. DOI: https://doi.org/10.1038/sdata.2017.202
Year of publication	2018

IUCN Red List

Description	Information database on extinction risk status, population dynamics and ecology of animal, plant and fungus species.
Source	IUCN. (2023). The IUCN Red List of Threatened Species. [On-line]. https://www.iucnredlist.org
Year of publication	1964 – updated regularly

[34] GBIF: The Global Biodiversity Information Facility (2024) What is GBIF?. [On-line].

NASA MODIS

Description	Land cover based on spectro-temporal data from the Moderate Resolution Imaging Spectroradiometer composed of 15 land cover classes: evergreen needle-leaved forests, evergreen broad-leaved forests, deciduous needle-leaved forests, deciduous broad-leaved forests, mixed forests, open shrublands, woody savannas, savannas, grasslands, permanent wetlands, croplands, urban and built-up lands, cropland/ natural vegetation mosaics, barren, water bodies.[35]
Source	Friedl, M., Sulla-Menashe, D. (2022). MODIS/Terra+Aqua Land Cover Type Yearly L3 Global 500m SIN Grid V061 [Data set]. NASA EOSDIS Land Processes Distributed Active Archive Center. https://doi.org/10.5067/MODIS/MCD12Q1.061
Year of publication	2022
Spatial resolution	World-wide, 500m
Temporal resolution	Yearly, 2001 – 2022

PEST-CHEMGRIDS

Description	PEST-CHEMGRIDS is a database gathering estimated application rates for 20 of the most used pesticides for 10 of the most cultivated crops.
Source	Maggi, F., et al. (2019). PEST-CHEMGRIDS, global gridded maps of the top 20 crop-specific pesticide application rates from 2015 to 2025. Sci Data 6, 170. https://doi.org/10.1038/s41597-019-0169-4
Year of publication	2019
Spatial resolution	5 arc-min
Temporal resolution	Yearly, 2015 – 2025

Protected Areas

Description	Geographic areas where wildlife protection regulation is implemented regarding human and economic activities.
Source	AXA Climate
Year of publication	Variable
Spatial resolution	Variable
Temporal resolution	2023

[35] Friedl, M., and Sulla-Menashe, D., - Boston University and MODAPS SIPS - NASA. (2015). MCD12Q1 MODIS/Terra+Aqua Land Cover Type Yearly L3 Global 500m SIN Grid. NASA LP DAAC.

SBTN Sectoral Materiality Tool for Step 1a

Description	Tool rating the impact by nature pressures of economic production processes by ISIC category.
Source	SBTN & UNEP-WCMC (2021). SBTN Sectoral Materiality Tool for Step 1a (version 2 - July 2021) – Overview
Year of publication	2021

VIIRS – Light pollution

Description	Based on remote sensing satellite, VIIRS (visible and infrared imaging suite) satellite provided imagery to assess annual night lights through monthly data of cloud-free average radiance grids.
Unit	nW/cm2/sr
Source	Elvidge, C.D., et al. (2021). Annual Time Series of Global VIIRS Nighttime Lights Derived from Monthly Averages: 2012 to 2019. Remote Sensing 2021, 13(5), p.922. DOI: https://doi.org/10.3390/rs13050922
Year of publication	2021
Spatial resolution	15 arcsecond
Temporal resolution	Yearly, 2012 to 2021

Appendix 2. Additional data sources

1. Comparison between ESA & MODIS

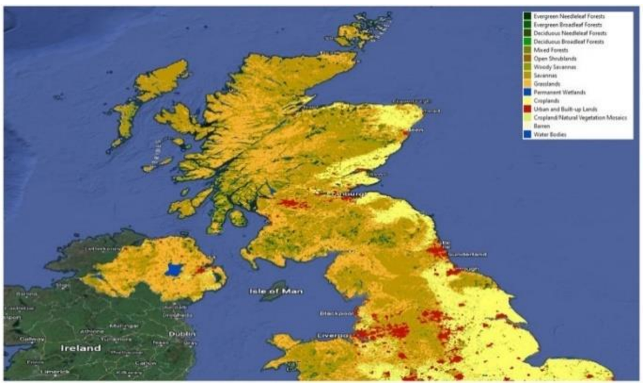
Interesting indicators at the country level can be derived from LULC, such as the proportion of natural or artificial LULC by country, the evolution over time or even deforestation (cf. section B). However, such calculations depend highly on the data source. For instance, Figure 13 compares LULC data from ESA WorldCover with a 300m resolution (left) and NASA MODIS with a 500m resolution (right). Both cover different large categories encompassing natural vegetation and non-vegetation classes as well as human-altered classes.

While results are mostly consistent between the two data sources, ESA World Cover displays a more refined cartography. For instance, it highlights sparse vegetation and barren areas instead of grasslands in the central Scottish Highlands. Such differences influence the representation of the different ecosystem types that could occur within these LULC and so, their habitat suitability. For example, field scabious (*Knautia arvensis*) is endemic to common grassland and never occurs in sparse vegetation or barren habitats in the more mountainous part of the Highlands, unlike alpine pearlwort (*Sagina saginoides*).

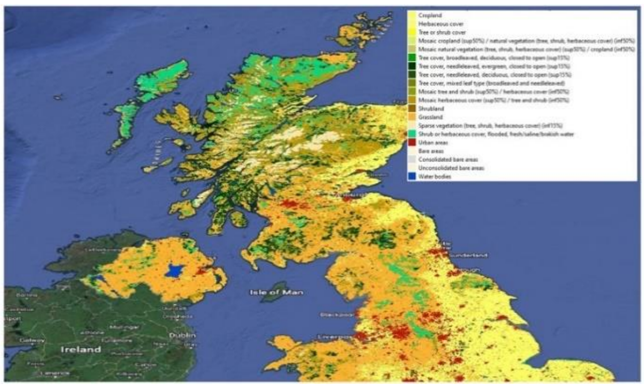
As such, while either LULC map can be used for assessing connectivity and fragmentation of territories, measuring theoretical species diversity or influencing restoration campaigns, the accuracy of the data must be challenged with respect to the intended goal.

Figure 13. LULC cartography in 2020 from two different data providers

a. NASA MODIS: 500m spatial resolution



b. ESA World Cover: 300m spatial resolution



Source: AXA Climate

2. Light pollution

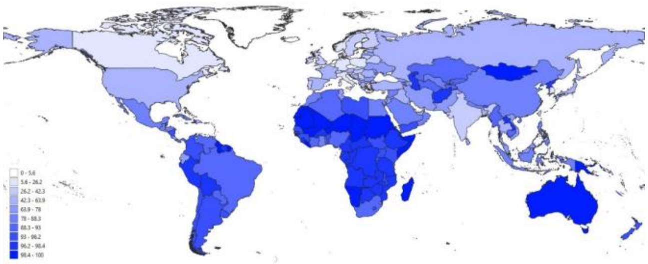
Light pollution strongly disturbs ecosystems and wildlife. For instance, it alters circadian rhythms, hunting or reproductive behaviours and shortens insects' life spans by burning on lamps.

Light pollution mapping is available through VIIRS data which displays the zenith sky brightness. At the country level, this indicator can be used to highlight the disturbance to ecosystems - as the average or total quantity of light emitted at night or as the density of light emitted in the country territory. Conversely, preserved environments can be identified through the surface per country without any light pollution.

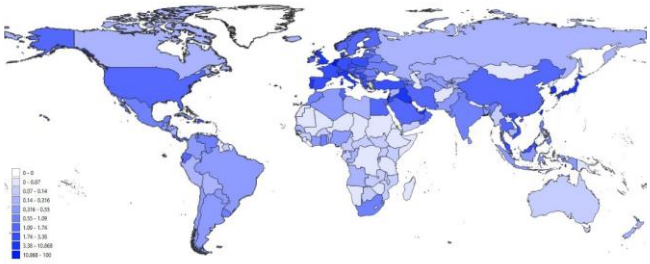
Figure 14 shows both the percentage area of each country wherein light emission is not considered brighter than the night sky and so, does not impact wildlife (< 0.5 nW/cm2/sr),[36, 37] and the percentage of each country wherein emissions are above medium (from medium to large towns:10 nW/cm2/sr).[38] It is worth noting that in the first case (Figure 14a), results for countries near the polar circle are not indicative as they do not have dark nights half of the year. For other countries, both metrics represent a similar situation, while showing some discrepancies in the rankings.

Figure 14. Light pollution per country based on VIIRS data

a. Percentage of country surface where emissions are below or comparable to those of the night sky



b. Percentage of country surface where emissions are above medium



Source: AXA Climate

[36] Hügli, F. (2021). Light pollution in European protected areas: Spatial variation of light pollution in Natura 2000 sites of the Member States of the European Union [Master thesis in Environmental Science], ETH Zurich.

[37] Widmer, K., et al. (2022). Review and Assessment of Available Information on Light Pollution in Europe (Eionet Report – ETC HE 2022/8), ISBN 978-82-93970-08-8, ETC HE c/o NILU, Kjeller, Norway.

[38] Hale, J. and Arlettaz, R., (2019). Artificial lighting and Biodiversity in Switzerland, technical report v4, University of Bern, 140.

Appendix 3. Impact scores table

Table 3. Example of impact scores calculated from the SBTN Sectoral Materiality Tool for Step 1a for each ISIC Rev 4 section[39]

ISIC rev 4	Mean impact score	Land/water/sea use change	Resource exploitation	Climate change	Pollution	Invasives and other
A	3.32	3.81	3.26	4.50	2.90	2.75
B	3.73	3.74	4.40	4.52	3.37	3.59
C	3.42	3.26	3.75	4.57	3.23	3.03
D	3.40	3.31	3.70	4.60	3.09	3.29
E	3.18	3.00	3.00	5.00	3.00	3.00
F	3.32	3.46	3.48	4.48	2.94	3.16
G	3.28	3.23	3.43	4.67	3.04	3.12
H	3.40	3.23	3.33	4.52	3.16	3.54
I	3.20	3.00	3.00	4.77	3.00	3.23
J	3.28	2.81	3.53	4.84	3.21	3.24
K	1.89	1.00	1.00	2.11	2.27	0.00
L	2.74	2.25	3.00	4.00	2.75	2.33
M	3.34	3.10	3.52	4.75	3.22	3.05
N	3.27	2.85	3.36	4.84	3.19	3.18
O	3.35	3.00	3.50	4.86	3.27	3.00
P	3.33	3.00	3.50	5.00	3.25	3.00
Q	3.32	3.00	3.75	4.17	3.17	3.00
R	3.27	3.00	3.43	5.00	3.17	3.00
S	3.29	2.78	3.50	5.00	3.25	3.00
T	ND	ND	ND	ND	ND	ND
U	3.33	3.00	3.50	5.00	3.25	3.00

***A:** Agriculture, forestry and fishing; **B:** Mining and quarrying; **C:** Manufacturing; **D:** Electricity, gas, steam and air conditioning supply; **E:** Water supply, sewerage, waste management and remediation activities; **F:** Construction; **G:** Wholesale and retail trade, repair of motor vehicles and motorcycles; **H:** Transportation and storage; **I:** Accommodation and food services activities; **J:** Information and communication; **K:** Financial and insurance activities; **L:** Real estate activities; **M:** Professional, scientific and technical activities; **N:** Administrative and support services activities; **O:** Public administration and defense, compulsory social security; **P:** Education; **Q:** Human health and social work activities; **R:** Arts, entertainment and recreation; **S:** Other services activities; **T:** Act. Of HH as employers, undif. G&S-producing activities of HH for own use; **U:** Activities of extraterritorial organisations and bodies*

[39] OECD (2019) OECD Stat – Value added and its components by activity, ISIC rev4.

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London Stock Exchange Group plc

10 Paternoster Square

London EC4M 7LS

Telephone +44 (0)20 7797 1000

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