Index Insights | Sustainable Investment

Quantifying the Unseen:

Building a Nature and Biodiversity Risk-Adjusted Sovereign Index

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FTSE RUSSELL
An LSEG Business

AXA Climate

Overview

Nature and biodiversity are increasingly recognised as material factors in corporate governance and investment decision-making. This shift reflects a growing understanding of the systemic risks that environmental degradation poses to businesses and economic stability.

While methodologies have been developed to incorporate nature-related risks into asset classes such as equities, corporate bonds, infrastructure, and private equity, their application to sovereign debt remains limited and underexplored.

Nonetheless, governments are stewards of vast natural assets and highly exposed to ecosystem degradation. As the materiality of nature loss becomes more evident—from reduced agricultural productivity and water stress to increased disaster vulnerability—it is essential to integrate ecological considerations into sovereign risk frameworks.

To help investors start their journey towards nature analyses at the country-level, we published a first paper called “Mapping the unseen: Unveiling nature and biodiversity data for sovereigns”. This first paper aimed to provide clarity on the main nature-related concepts and to survey the datasets to be used for a sovereign assessment.

This second report sets out to design a robust methodology to bring nature into sovereign analysis, and to implement it concretely. The proposed framework is structured around three pillars: the impacts of a country on biodiversity, its dependencies to nature services, and the policies put in place by the country to preserve nature. The paper then illustrates this approach by outlining how to calculate scores for a selected group of countries and tilt a traditional sovereign index to account for these nature-related risks.

Our research demonstrates that greater recognition of ecological resilience and vulnerability can shift our understanding of a sovereign asset and impact the risk-return profile of a sovereign portfolio—laying the groundwork for more forward-looking, sustainable investment and policy decisions.

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Introduction

Biodiversity is declining at an unprecedented rate, driven primarily by human activities such as land-use change, overuse of natural resources, pollution, climate change, and the spread of invasive species. With a 73% decline in the average size of global wildlife populations in 50 years, according to the World Wildlife Fund's Living Planet Report 2024 [1], the stability of ecosystems that underpin human society and its economy is under threat.

The consequences of these losses may be as varied as depletion of natural capital resources, supply chain disruption, decreases in crop yields due to an insufficient number of pollinators [2] or sanitary risks.

Governments have a dual relationship with biodiversity: they rely on natural resources for economic stability while also shaping biodiversity outcomes through policies on land use, agriculture, regulation, and conservation. Biodiversity loss can lead to sovereign credit risk by affecting agricultural productivity, increasing disaster recovery costs, and weakening long-term economic resilience. Conversely, proactive biodiversity management can enhance creditworthiness by preserving natural assets and mitigating environmental risks.

The sovereign debt market consists of government-issued bonds that help finance public expenditures. Investors assess sovereign creditworthiness based on economic indicators, fiscal policies, and geopolitical stability. Traditionally, environmental factors have been secondary considerations, but this is changing as nature-related risks gain prominence and nature degradation could in turn impact the valuations of sovereign bonds.

Nevertheless, sovereign wealth funds and institutional investors can take steps to strengthen the resilience of their portfolios against environmental and social shifts by integrating nature-related risks into financial decision-making.

Some initiatives have been studying the interactions between nature and the sovereign market, such as the Climate and Nature Sovereign Index (CNSI) [3] developed by WWF in collaboration with Ninety One, the Sovereign Biodiversity Index (SBI)[4] designed by Ninety One, or the Nature and Climate Sovereign Bond Facility [5] proposed by Finance for Biodiversity (F4B)—see Appendix 1 for more details on these initiatives.

LSEG and AXA Climate also collaborated on preliminary research to address the challenges of integrating biodiversity data into sovereign investment strategies [6]. The study underscored the financial implications of biodiversity loss and the need for improved data integration in sovereign investment decisions. It also provided a guide to some available datasets and emphasised the importance of selecting relevant indicators for sovereign credit analysis.

The present research of AXA Climate and FTSE Russell picks up on this previous work and looks at how these relevant indicators can be computed concretely to assess the different dimensions of nature-related risks at the country level and integrated into a government bond index.

1. A three-pillar framework to assess sovereign biodiversity-adjusted risks

Integrating nature into sovereign analysis requires a fundamental shift in how national risks are understood and assessed. Indeed, evaluating biodiversity-related risks for countries involves a multifaced approach. Countries are deeply embedded in—and reliant on—natural systems: they both impact and depend on biodiversity, while also holding responsibility for its stewardship through governance and policy.

To capture this multidimensional relationship, we propose a framework based on three pillars:

– **Impacts**, reflecting a country's pressure on biodiversity.

– **Dependencies**, measuring how much a country's economy and population rely on healthy ecosystems and the services they provide.

– **Policy**, assessing the strength and effectiveness of national governance in protecting and restoring nature.

This tripartite framework (Figure 1) enables a more nuanced and actionable understanding of nature-related risks for sovereigns.

Figure 1: Nature and biodiversity sovereign risk assessment framework

Source: AXA Climate and FTSE Russell. The list of indicators, descriptions and data sources are available in Appendix 2.

1.1 The Impacts pillar

The Impacts Pillar addresses the effects of human activities on natural capital, including ecosystems, biodiversity, and natural resources. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) [7] has categorised these impacts into five direct drivers of biodiversity loss: climate change, land use change, overuse of natural resources, pollution, and invasive species. By quantifying each of these pressures, it is possible to estimate and compare impact-related risks to identify countries with the highest nature-related impacts and, consequently, the greatest risks of natural capital collapse.

– **Climate change** affects biodiversity through various mechanisms, including the spatial change of bioclimatic conditions reducing or shifting species' suitable habitats, and the acidification of oceans. *LSEG Sovereign Sustainability Solutions* quantifies country-level impacts using indicators like the GDP-Adjusted Carbon Footprint, which compares a country's emissions to peers with similar income, and the NDC Implied Temperature Rise, estimating global warming in 2100 if all countries matched a given nation's carbon overshoot.

– **Land use change** reduces natural and semi-natural areas, leading to habitat loss for most species [8] and increased landscape fragmentation—a major driver of biodiversity loss. Fragmentation disrupts species' biological cycles, reduces their territories and movements, leading to increased mortality, population decline, and loss of genetic diversity, ultimately resulting in extinction [9].

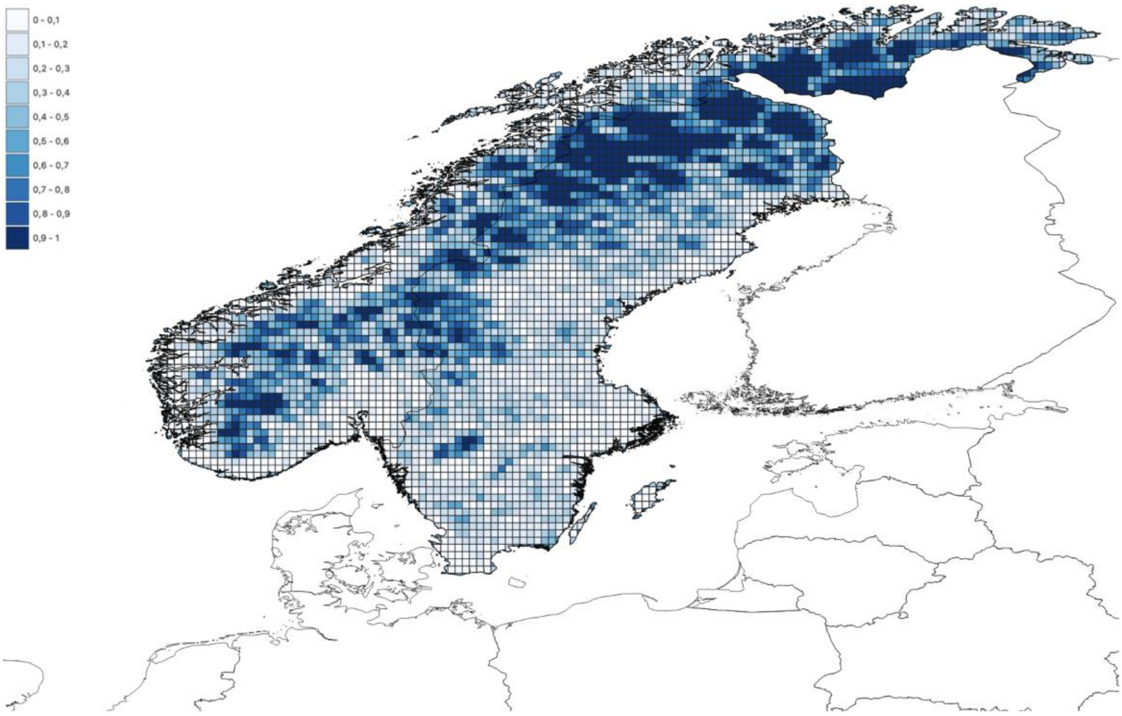
  Both land use change and fragmentation are evaluated using the Dynamic World satellite-based land cover maps with a high resolution of 10m. These spatially explicit land-cover distributions allow measuring the percentage of natural and semi-natural land by country. Fragmentation is assessed by examining the probability that two individuals are situated within the same patch of natural or semi-natural habitat (Figure 2), which serves as a basis for estimating the average landscape coherence in each country (Figure 3). The countries' land cover evolutions are also considered, by measuring (i) the trend of artificialisation over the past four years and (ii) calculating the relative change in fragmentation compared to its value four years ago.

– **Resource use deficit** refers to the extraction of natural resources at an unsustainable rate. This aspect is proxied by the Global Footprint Network calculation of countries' Overshoot Days which indicates for each year the date on which a country's per person consumption exceeds what the planet's ecosystems can regenerate per person. The earlier the date, the more the country is consuming at a level that cannot be replicated globally. Then, the consumption trajectory of each country's resource consumption is assessed by the change in the per person consumption levels over the past five years.

– **Pollution** encompasses the impact of multiple types of pollution—light, pesticide, fertilizer and solid waste—directly impacting biodiversity and ecosystems. They are assessed using data from VIIRS satellite sensors, FAO databases, and the World Bank, OCDE, and EuroStat databases, respectively. While the indicators relating to pesticide, fertilizer and solid waste can be used directly as indicators using their measured quantities, light pollution is computed as the proportion of each country where light emissions are not considered to exceed the night sky and have little impact on wildlife.

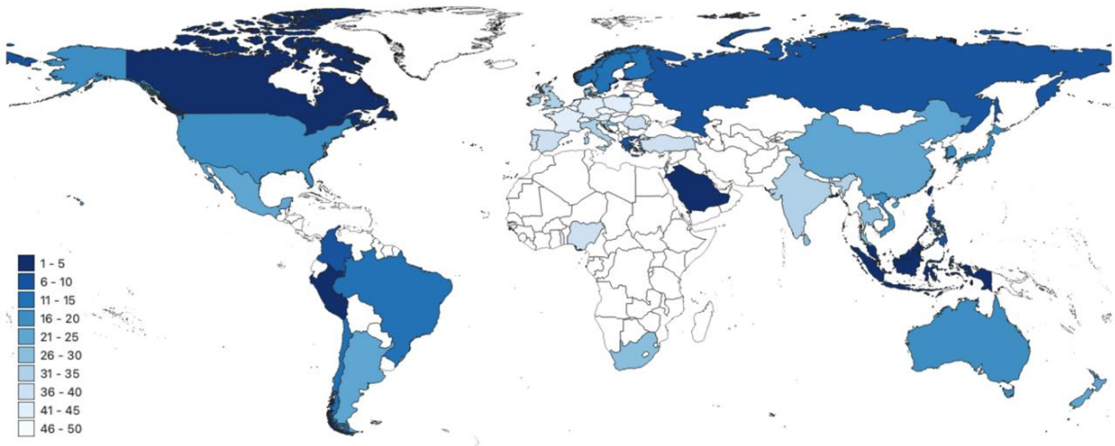
– **Invasive species** threaten ecosystems by destabilising them, which can, in some cases, lead to collapse. In practice, both predicting and assessing their impact is challenging. However, the greater the number of invasive species in any place, the higher the risk to local biodiversity. The Global Register of Introduced and Invasive Species (GRIIS) compiles lists of invasive species for each country. To proxy the potential pressure from this threat, the number of unique invasive species per country, as reported by GRIIS, is computed relative to each country's known biodiversity.

Figure 2: Map of Coherence (example of Sweden and Norway's landscapes). Using land use change data, we develop a Map of Coherence, i.e. the probability that two individuals will be found within the same patch, on a 0.2° grid.



Source: AXA Climate.

Figure 3: Countries ranked according to the Landscape Fragmentation Indicator. Higher ranked countries (i.e. with the least landscape fragmentation) in dark blue and the lower-ranked countries in light blues (i.e. with the largest landscape fragmentation).



Source: AXA Climate.

1.2 The Dependencies pillar

The Dependencies pillar assesses how much a country's economy relies on nature's contributions--known as ecosystem services—such as provision of food, clean water, pollination, and erosion control. These services underpin many economic activities and are necessary for human well-being. Understanding these dependencies is critical for identifying a country's vulnerability to biodiversity loss and ecosystem degradation.

Assessing these dependencies at the country scale can be done by looking at three different aspects:

– **Spatial dependency** captures the degree to which a country relies on its natural habitats and the ecosystem services they provide. Each year, the WWF physical risk filter [10] assigns a physical risk score to countries associated with the provision of ecosystem services. Based on these scores, the spatial dependency indicator for each country is defined as the normalised highest score across ecosystem service categories, including Provisioning services, Regulating and supporting services (Enabling), Regulating services (Mitigating), Cultural services.

– **Sectoral dependency** examines the reliance of each country's most represented economic sectors on nature. The ENCORE (Exploring Natural Capital Opportunities, Risks and Exposures) database compiles scores on the impact and dependencies of many economic sectors. The World Bank and OECD databases provide GDP sector compositions [11], broken down into agriculture, industry and services, enabling the weighting of each sector's contribution to a country's economy. The sectoral dependency indicator is computed by weighting the average ENCORE dependency score related to each of these three main sectors by their associated GDP share.

– **Physical risks exposure** measures how much a given area is exposed to climate hazards, such as heatwaves and floods. This directly affects the provision of ecosystem services and reflects dependencies on stable natural conditions. The physical risk exposure of each country is quantified using indicators from LSEG Sovereign Sustainability Solutions; Historical Physical Risk and the Delta 2050 Physical Risk. These indicators assess a country's overall physical climate risk level by averaging its three highest hazard-specific risk scores and considering the impact of sectoral vulnerability. The former is based on historical data relating to current exposure, while the latter assesses the expected trend up to 2050 based on the IPCC SSP5-8.5 scenario.

1.3 The Policy pillar

The Policy pillar evaluates actions and strategies implemented by a country to reduce negative impacts on biodiversity and promote conservation and sustainable use of natural resources.

This includes legislative measures on:

– **Species threat levels and protection,** both vital for conservation efforts. They are evaluated based on diverse sources of reported estimates for threatened species, mostly red lists—thanks in large part to the efforts of the IUCN—and from legal documents for protected species. The associated indicator evaluates the number of species reported as threatened or protected at the country level, the extensiveness of reigns and taxa considered, data accessibility and recency, and the existence of dedicated laws. This combined information supports an overall evaluation of a country's efforts in species monitoring and protection, categorised as low, medium, or high.

– **Ecosystem protection** assessed by the extent and management effectiveness of protected areas declared within a country's territory. It is measured as the percentage of each country's terrestrial and marine protected areas which is effectively protected by laws or treaties for nature-related purposes.

– It also includes **adaptation plans** registered with the United Nations and linked to either biodiversity (National Biodiversity Strategy and Action Plan (NBSAP)) or climate change (National Adaptation Plan (NAP)). This reflects a country's strategic approach to managing future environmental challenges. Both indicators are measured as Yes or No, depending on whether the country has submitted the respective plan.

1.4 Pillar Scores

To calculate each country's nature score for a given pillar, we follow a two-step process involving data transformation and aggregation.

Step 1: Standardising the data

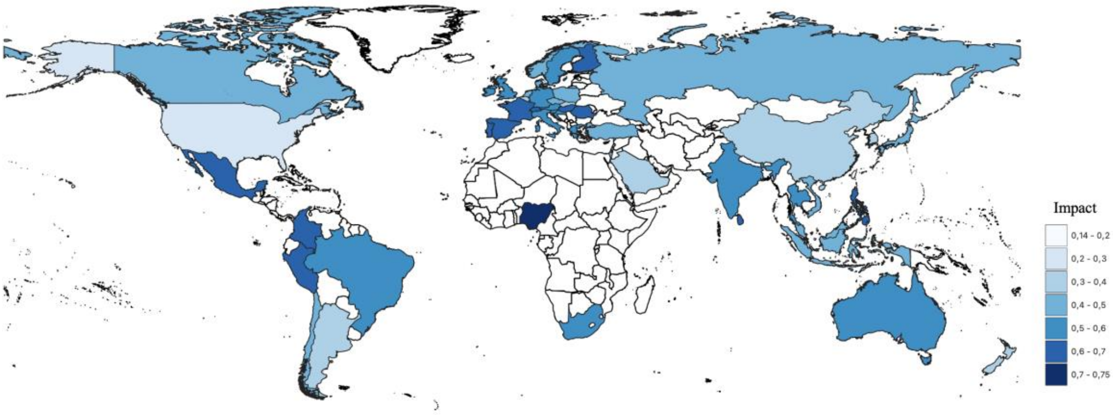
Raw indicators values—each with different units and scales—are converted into standardised scores. This begins with the calculation of *z-scores*, which measure how far each country's value deviates from the average of a reference group of fifty-three investable countries. For indicators with extreme outlier values, a technique called *winsorisation* is applied, to limit their influence by capping possible values.[1] These *z-scores* are then transformed into *s-scores*, which range from 0 to 1, using a statistical method called the cumulative normal distribution.

Step 2: Aggregating the scores

Once all indicators are standardised, the indicator scores are aggregated to create scores for each pillar. This is done by giving equal weight to each indicator within its sub-pillar, and to each sub-pillar within its pillar. If a country is missing data for some indicators, the sub-pillar score is calculated using only the available data.

Figures 4, 5, and 6 illustrate the impact, dependence, and policy scores respectively, while a comprehensive list of all scores is provided in Appendix 3.

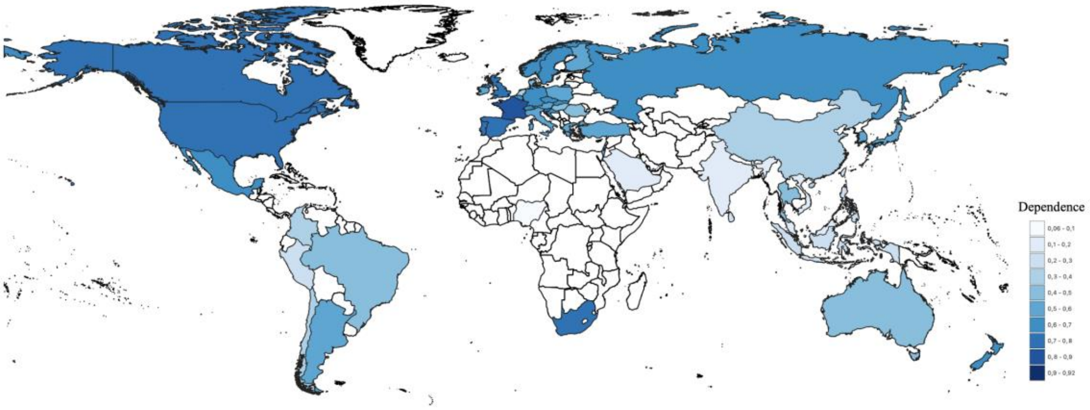
Figure 4. Country level impact scores. Higher impact scores signify better performance.



Source: AXA Climate and FTSE Russell. Detailed pillar scores are available in Appendix 3.

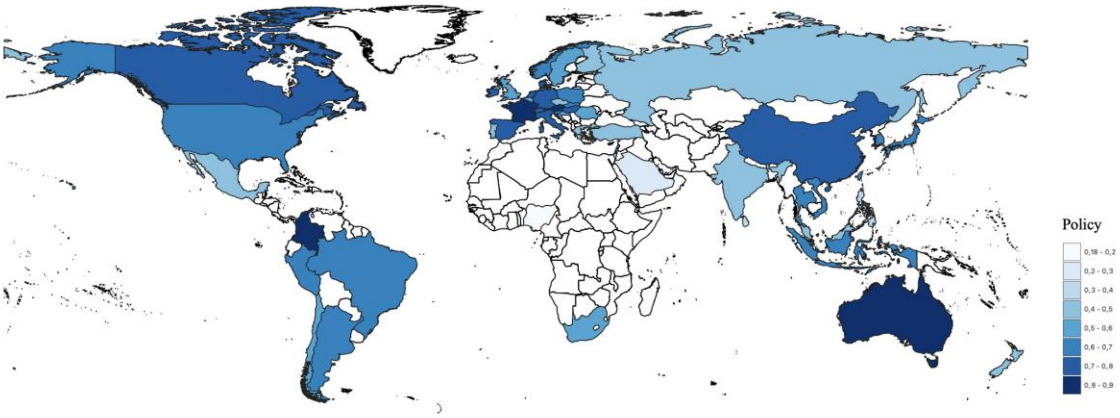
[1] The maximum and minimum capping values are defined respectively as $Min_{value} = Q_1 - (1.5 * IQR)$ and $Max_{value} = Q_3 + (1.5 * IQR)$, where IQR is the interquartile range, $Q_1$the first quartile and Q_3 the third quartile.

Figure 5. Country level dependence scores. Higher dependence scores signify better performance.



Source: FTSE Russell. Detailed pillar scores are available in Appendix 3.

Figure 6. Country level policy scores. Higher policy scores signify better performance.



Source: FTSE Russell. Detailed pillar scores are available in Appendix 3.

2. Building a Nature and Biodiversity Risk-Adjusted Sovereign Index

Building on the pioneering methodology of the FTSE Climate Risk-Adjusted Government Bond Index Series[2] developed in 2019, this study examines a nature and biodiversity risk-adjusted variant: a Nature and Biodiversity Risk-Adjusted World Government Bond Index. Such an index represents the first-of-its-kind integration of nature and biodiversity-related risks into sovereign bond investment strategies. This innovative approach reflects the growing awareness that nature and biodiversity loss is not only an environmental issue but also a material financial risk—especially for sovereign issuers whose economies depend on and impact biodiversity.

A multi-pillar tilting approach

The simulated Nature and Biodiversity Risk-Adjusted World Government Bond Index employs a multi-factor tilting methodology that adjusts the market value weights of sovereign bonds based on the three nature and biodiversity-related pillars detailed in Part 1.

- **Impacts**: The pressure a country exerts on biodiversity (e.g., land-use change, pollution, invasive species).
- **Dependencies**: The extent to which a country's economy relies on ecosystem services (e.g., agriculture, forestry, fisheries).
- **Policy**: The strength and credibility of national biodiversity strategies and conservation efforts.

Each country receives a composite biodiversity score derived from these three pillars. The scores are then used to geometrically tilt the weights of sovereign bonds in the index.

Data normalisation and tilting methodology

Step 1: Building the composite biodiversity score

First, the composite biodiversity score CBS for country i is constructed as follows:

$$CBS_i = Impact_i^{\alpha} * Dependence_i^{\beta} * Policy_i^{\gamma}$$

Where $Impact$, $Dependence$, and $Policy$ are the scores for each corresponding pillar, and α, β, and γ represent the tilt powers applied to each pillar respectively.

[2] For further details on the FTSE Climate Risk-Adjusted Government Bond Index Series, please see FTSE Climate Risk-Adjusted Government Bond Index Series | LSEG.

Step 2: Standardising the scores

The country composite biodiversity score for country i is converted into a $z\text{-}score$ relative to the cohort of countries in the parent index, as follows:

$$z\text{-}score_i = \frac{CBS_i - \mu_{CBS}}{\sigma_{CBS}}$$

Where μ and σ are the cross-sectional mean and standard deviation, respectively.

Then, a two-step procedure is used to compute standardised $s\text{-}scores$ between 0.1 and 1:

1. $z\text{-}scores$ are mapped to $s\text{-}scores \in [0, 1]$ using the cumulative distribution function of the standard normal distribution.
2. A linearisation process[3] is applied to the $s\text{-}scores$ to introduce a 0.1 floor such that $s\text{-}scores \in [0.1, 1]$.

Step 3: Calculating adjusted weights

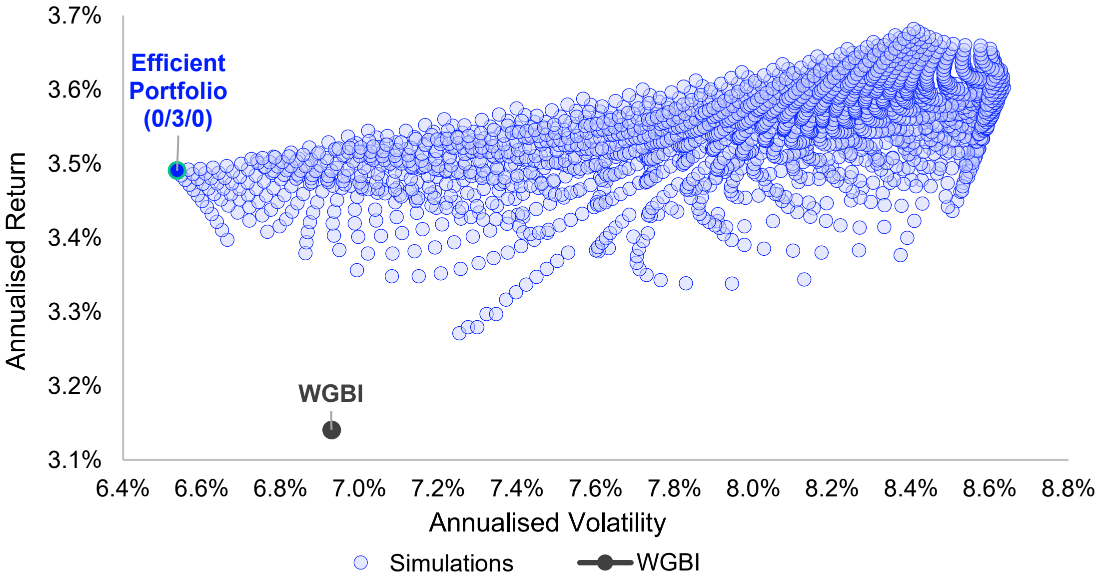
These standardised $s\text{-}scores$ are applied to each country's market value weight ω_i in the parent index to derive the adjusted weights θ_i. For n countries in the parent index:

$$\theta_i = \frac{s\_score_i * \omega_i}{\sum_{i=1}^{n}(CBS_i * \omega_i)}$$

Index construction and simulations

To identify the combinations of tilts α, β, and γ that most effectively reduce nature and biodiversity risks without compromising index performance, a large number of combinations is simulated. Tilts for each of the three pillars are varied from 0 to 3 in increments of 0.25, resulting in $(3/0.25 + 1)^3 = 2{,}197$ combinations of tilts. Using index data from December 2001 to April 2025, Figure 7 plots these combinations, with annualised return on the Y-axis and annualised volatility on the X-axis.

Figure 7: Efficient frontier—Simulations on Impact, Dependence, and Policy (from 0 to 3 with a 0.25 step), USD unhedged



Source: FTSE Russell, data from December 2001 to April 2025. The results shown reflect back-tested performance. Please see disclaimer for further information.

[3] $S\text{-}scores$ stand for standardised scores and are computed as follows: $s\text{-}score(X_i) = \left((X_i - \min_X X)/(\max_X X - \min_X X)\right) * 0.9 + 0.1$, where X denotes the Impact, Dependence, or Policy score and i denotes a country. Those $s\text{-}scores$ are thus relative to the index assessment cohort and may change accordingly.

The resulting efficient frontier offers valuable insights. First, over the analysis period, USD unhedged annualised returns consistently outperform those of the parent index, the WGBI. Second, several simulations show reduced annualised volatility compared to the WGBI. And third, the portfolio that maximises return while minimising volatility—identified as the efficient portfolio in the Figure 7—corresponds to a tilt configuration of 0 for Impact, 3 for Dependence and 0 for Policy.

However, this configuration is not desirable, as it excludes the Impact and Policy pillars. A more refined selection is necessary, achieved through sensitivity analysis, which isolates the effect of varying the tilt of each pillar, *ceteris paribus*, on various financial and nature-related metrics. Figures 8 to 14 illustrate these sensitivities: the blue curve shows variations in the Impact pillar, green curve that of the Dependence pillar, and the purple curve that of the Policy pillar. The dotted orange line represents the WGBI benchmark.

Figure 8: Sensitivity analysis on annualised returns

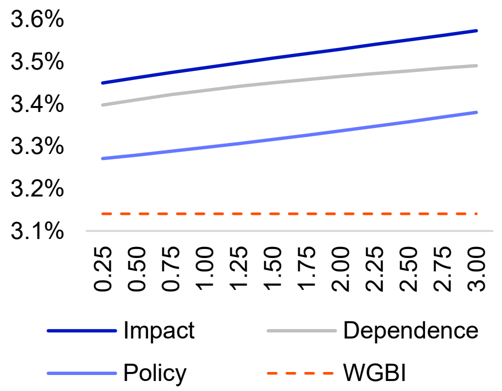


Figure 9: Sensitivity analysis on annualised volatility

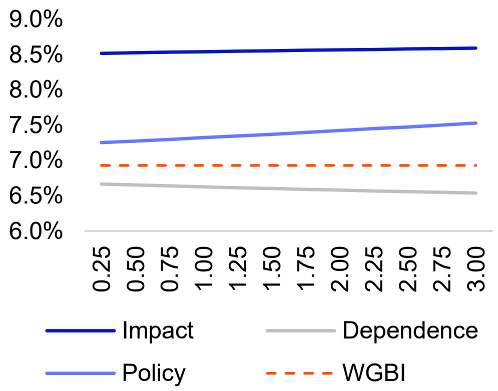
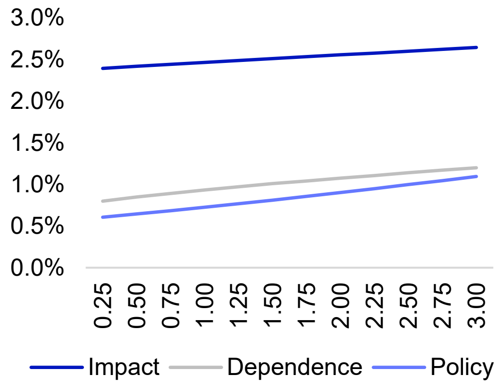


Figure 10: Sensitivity analysis on annualised tracking error



Source: FTSE Russell, data as of April 30, 2025.

As previously shown, varying the tilts of each of the three pillars enables consistent outperformance of the WGBI's annualised returns (Figure 8). The observed positive correlation between tilt values and annualised returns suggests that increasing the tilt of the Impact pillar yields the greatest improvement in returns, followed by the Dependence pillar and then the Policy pillar.

Regarding volatility (Figure 9), the data indicates that increasing the tilt of the Impact pillar consistently raises annualised volatility above that of the WGBI. A similar pattern is evident for the Policy pillar. In contrast, an increase in the tilt of the Dependence pillar is associated with a negative correlation to annualised volatility. This implies that enhancing the tilt of the Dependence pillar may help stabilise volatility keeping it close to the WGBI's level through a compensatory effect.

The sensitivity analysis of annualised tracking error in response to tilt variations (Figure 10) provides further insight. Raising the tilt of the Impact pillar leads to a marked increase in annualised tracking error, while those of the Dependence and Policy pillars remain within a range of 60 to 120 bps. This argues in favour of applying higher tilts to the Dependence and Policy pillars compared to the Impact pillar.

Figure 11: Sensitivity analysis on Impact weighted average

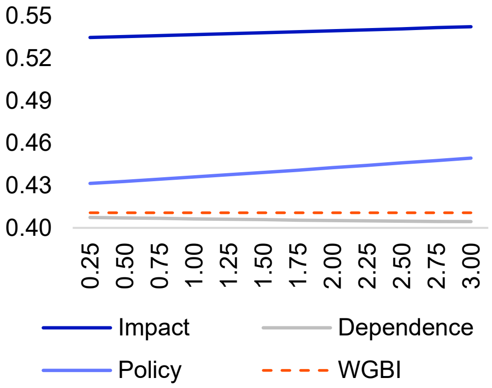


Figure 12: Sensitivity analysis on Dependence weighted average

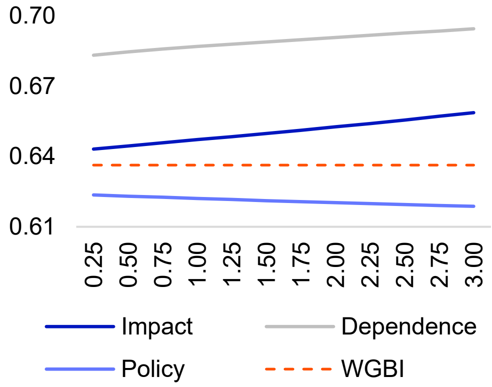


Figure 13: Sensitivity analysis on Policy weighted average

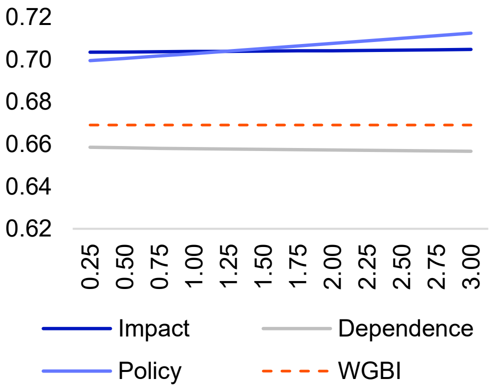
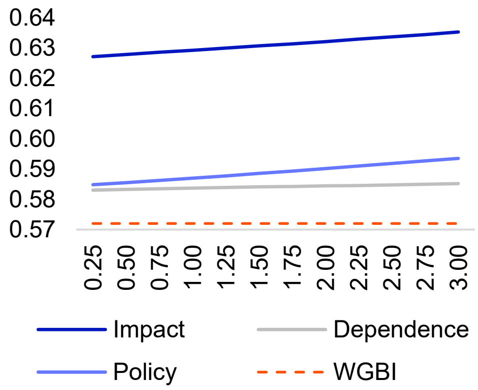


Figure 14: Sensitivity analysis on Composite Biodiversity weighted average



Source: FTSE Russell, data as of April 30, 2025.

Figures 11 to 14 illustrate how variations in tilts affect the weighted averages of each pillar scores, as well as the Composite Biodiversity score. These weighted averages are constructed using each country's weights from the tilted index, based on the corresponding tilts, and are compared against the WGBI's weighted averages. As expected, increasing the tilt of a specific pillar results in a systematic increase in the weighted average of that pillar, thereby improving its value relative to the WGBI benchmark.

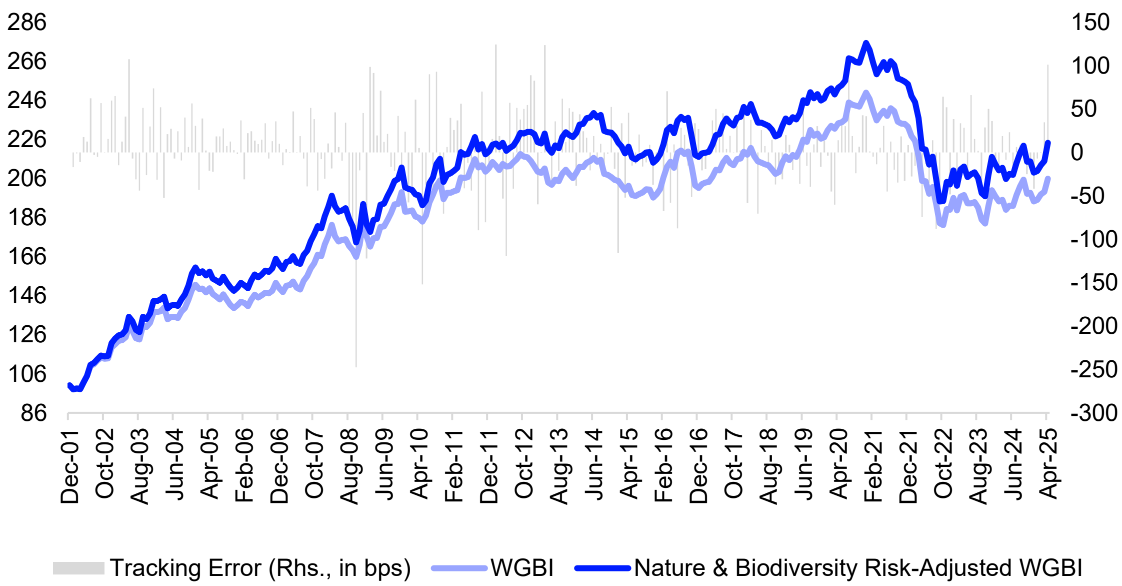
Simulations conducted using the tilting methodology demonstrate that biodiversity-adjusted indices can achieve meaningful alignment with nature and biodiversity objectives, improve returns and volatility, while maintaining low tracking error and an effective duration comparable to that of the parent index, namely the WGBI.

3. A first tilted index to illustrate concretely the application of this three-pillar framework

By arbitrating this analysis, we choose the following tilt configuration: $\alpha = 1$ for the Impact pillar, $\beta = 2$ for the Dependence pillar, and $\gamma = 1$ for the Policy pillar. This allocation reflects a strategic emphasis on economic dependence on nature, while still accounting for both environmental pressures and policy responses. At the same time, this tilt configuration enables outperformance relative to the WGBI, maintains volatility in line with the parent index, and keeps tracking error within acceptable limits.

Figure 15: Illustrates the simulation with the selected tilt configuration, i.e., 1 for Impact, 2 for Dependence, and 1 for Policy.

Figure 15: Nature and Biodiversity Risk-Adjusted World Government Bond Index vs parent index—Performance



Metric	WGBI	Nature & Biodiversity Risk-Adjusted WGBI
Annualised Return	3.14%	3.52%
1Y Return	8.32%	9.00%
YtD Return	5.99%	7.31%
Annualised Volatility	6.93%	7.62%
Risk-Adjusted Return	0.45	0.46
Annualised Tracking Error		1.55%
Return Correlation		98.16%
Yield to Maturity*	3.32%	3.36%
Effective Duration*	6.94	7.02
Number of Bonds*	1,323	1,323
Impact WA*	0.41	0.47
Dependence WA*	0.64	0.68
Policy WA*	0.67	0.69
N&B Aggregated WA*	0.57	0.61

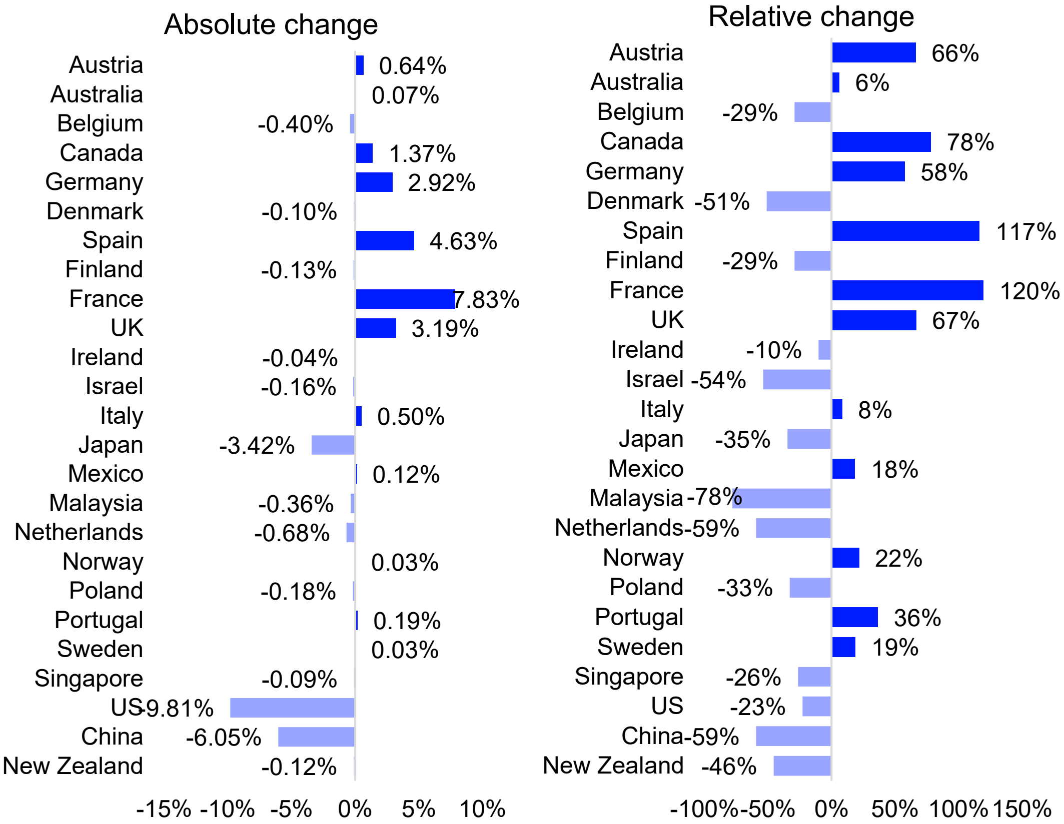
Source: FTSE Russell, data from December 2001 to April 2025. The results shown reflect back-tested performance. Please see disclaimer for further information.

* April 30, 2025 data.

This tilt configuration delivers higher returns than the WGBI, albeit with a modest increase in annualised volatility, offering a comparable risk-adjusted return ratio. Based on the earlier sensitivity analysis, achieving outperformance while simultaneously controlling both volatility and tracking error proves challenging. This is primarily due to the Impact pillar, which shows a positive correlation between its tilt value and both volatility and tracking-error (see Figures 9 and 10). Additionally, the effective duration of the simulated Nature and Biodiversity Risk-Adjusted World Government Bond Index is slightly longer than that of the WGBI.

In terms of constituents, countries with high biodiversity risk but low policy ambition (e.g., high-impact tropical economies) are underweighted, while those demonstrating strong conservation leadership and lower ecological pressure are rewarded with higher weights (Figure 16). More specific examples are detailed in Box 1.

Figure 16: Country weights in relative and absolute delta vs WGBI



Source: FTSE Russell, data as of April 30, 2025.

Box 1. Nature-risk spectrum: key insights for portfolio positioning

Spain

According to the index methodology, Spain ranks among the leading countries. Its weight increases from 3.98% in the parent index to 8.61% in the nature risk-adjusted index, reflecting an absolute change of 4.63 percentage points and a relative increase of 116.2%. This strong performance is underpinned by positive performance across the board: an impact score of 0.70, a dependence score of 0.74, and a policy score of 0.76 (Figure 17).

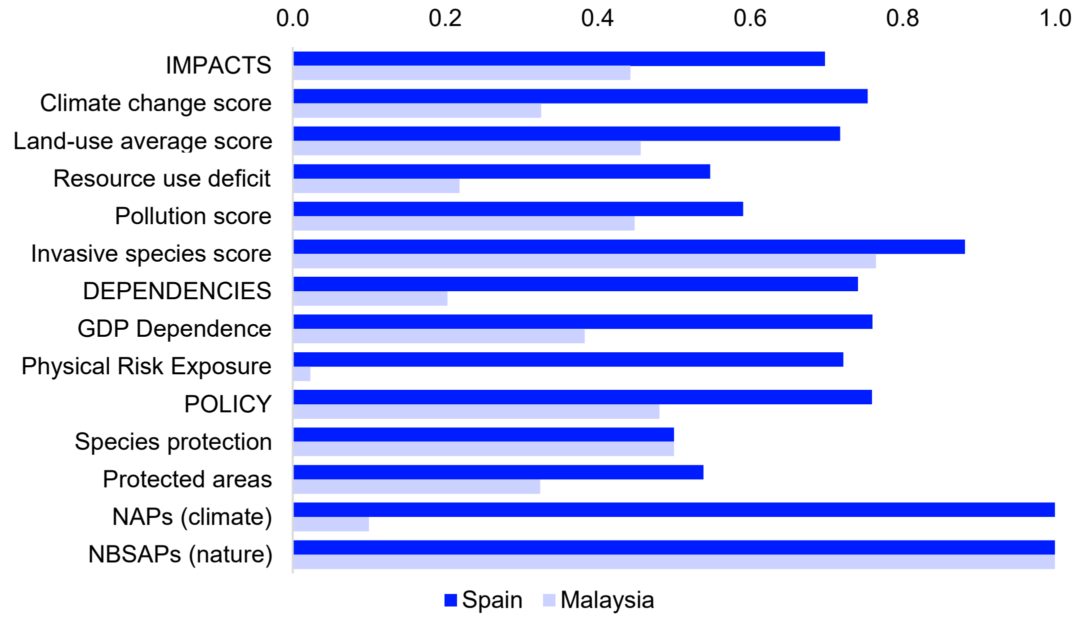
Spain stands out by having one of the highest rates of recent land cover change, with a 2.13% increase of natural and semi-natural habitats over five years. The country aligns with the Paris Agreement, with a projected temperature rise of 1.8°C by 2100 based on its Nationally Determined Contributions. It also maintains a low carbon footprint compared to peers with similar income levels. While Spain faces high physical risk exposure, its projected vulnerability by 2050 is comparatively lower than that of other countries in the cohort. Additionally, Spain shows a moderate but meaningful commitment to biodiversity conservation: 18% of its protected areas are effectively safeguarded by legislation, and the country has published both a National Biodiversity Strategies and Action Plan (NBSAP) and a National Adaptation Plan (NAP).

Malaysia

Malaysia ranks among the lowest in the cohort in the nature-risk assessment. Despite its modest weight in the parent index (0.46%), its representation drops sharply to 0.10% in the nature-risk-adjusted index—an absolute decrease of 0.36 percentage points and a relative reduction of 78%. This near exclusion is driven by weak performance across all pillars, with impact, dependence, and policy scores of 0.44, 0.20, and 0.48, respectively.

Malaysia is the most exposed country in the cohort to physical risks, both currently and in projections for 2050. On May 9th, it reached its 2025 Overshoot Day—marking the date when the country's ecological resource consumption exceeds the planet's annual biocapacity if replicated globally—earlier than it did five years ago. The country also exhibits high levels of ecosystem fragmentation and a carbon footprint that exceeds those of peers with similar income levels. From a policy perspective, Malaysia has limited protected area coverage and has yet to disclose a National Adaptation Plan (NAP), further underscoring its vulnerability in the face of nature-related risks.

Figure 17: Pillar and sub-pillar scores for Spain and Malaysia



Source: AXA Climate and FTSE Russell.

4. Discussion

While the simulated nature and biodiversity risk-adjusted world government bond index demonstrates promising performance, we recognise several caveats in the current framework that should be considered for future refinement.

- **Data access and quality**: A primary challenge lies in the availability and reliability of nature-related datasets—global datasets continue to improve, yet they still suffer from gaps in coverage, consistency, and granularity, particularly across diverse regions.
- **Temporal coverage:** The limited historical depth of biodiversity data constrains the ability to assess long-term impacts on sovereign risk and return profiles. However, the relatively slow-changing nature of biodiversity metrics may mitigate the effects of short-term data variability.
- **Data selection and processing:** Our framework underscores the importance of careful data source selection and processing. For instance, while multiple dimensions of biodiversity impact are captured, certain aspects—such as pollution—could be more precisely addressed by distinguishing between types, such as chemical versus plastic pollution. Acknowledging these limitations is crucial to building credible, comparable indicators that can meaningfully inform sovereign risk assessments and investment decisions.
- **Country selection and index scope:** The scores are calculated relative to a sample of fifty-three investable countries in fixed income markets. A such, the results are specific to this cohort and may differ with changes in initial country selection, such as by income level, geographic region, or expanded to include more countries.
- **Index construction methodology:** From an index construction standpoint, a tilting approach was used to adjust market weights, resulting in the under-or overweighting of certain countries. While this method preserves the multidimensional integration of nature-related risks in the index, alternative approaches—such as exclusions or target exposures—could offer different trade-offs. Future iterations may also explore capping mechanisms to manage relative weight shifts more effectively.

Conclusion

This report illustrates how a structured, three-pillar approach—capturing sovereign impacts on biodiversity, economic dependencies on natural capital, and the strength of policy responses—can be operationalised to integrate nature into sovereign risk assessments.

By translating these dimensions into quantitative scores and tilting a traditional sovereign index accordingly, this approach enables sovereign debt investors to (i) mitigate long-term nature-related risks in their portfolios, and (ii) signal support for countries implementing ambitious biodiversity policies.

Of course, further research is needed to deepen our understanding of the multiple dimensions of nature-related risks and to improve the datasets that are used to proxy these risks. Therefore, as new datasets and tools continue to emerge, careful attention must be paid to the selection of appropriate methodologies and proxies to ensure that indicators accurately reflect the ecological realities they aim to measure, avoiding both misinterpretation and unintended consequences.

In the meantime, the proposed Nature and Biodiversity Risk-Adjusted Government Bond Index represents nonetheless a concrete application of this three-pillar framework, offering a scalable, transparent, and holistic tool for integrating global nature goals into fixed income investments.

As the materiality of biodiversity loss becomes clearer, financial markets have a growing role to play in signalling and supporting effective national responses. Biodiversity-adjusted sovereign indices are thus not only timely but useful instruments to embed ecological resilience into mainstream investment decisions.

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Appendix 1: Mapping of existing initiatives on nature and sovereign analyses

Initiative	Description
Climate and Nature Sovereign Index (CNSI)	Developed by WWF in collaboration with Ninety One, the CNSI is a pilot framework designed to assess long-term risks related to climate change and biodiversity loss at a country level. The index uses real-time and forward-looking indicators to evaluate environmental sustainability and risk across sovereign debt markets. By integrating these factors, CNSI aims to help investors make more informed decisions while encouraging governments to adopt policies that enhance resilience against environmental threats. The index also supports the development of new financing mechanisms that align sovereign debt investment with sustainability goals. This initiative was an important first step in incorporating environmental risks into sovereign debt investing.
Sovereign Biodiversity Index (SBI)	The more recent SBI designed by Ninety One specifically measures government performance on nature and biodiversity. The index assesses how sovereign issuers impact biodiversity and the risks stemming from biodiversity loss, around three pillars –quality of nature, deforestation and policy. It provides a quantitative framework for investors to evaluate nature-related risks at the national level, helping them direct capital toward countries that actively safeguard biodiversity.
Nature and Climate Sovereign Bond Facility	Proposed by Finance for Biodiversity (F4B), this initiative seeks to integrate nature and climate considerations into sovereign debt markets. The facility is designed to support sovereign issuers and investors in addressing short-term debt crises while promoting long-term sustainability. It provides technical assistance, credit enhancement, and performance assessment services to help countries align their borrowing strategies with environmental and climate objectives.
LSEG and AXA Climate Research	LSEG and AXA Climate have collaborated on preliminary research to address the challenges of integrating biodiversity data into sovereign investment strategies. The study underscores the financial implications of biodiversity loss and the need for improved data integration in sovereign investment decisions. It also provides a guide to some available datasets and emphasises the importance of selecting relevant indicators for sovereign credit analysis.

Appendix 2: List of indicators descriptions and data sources

Pillar	Sub-pillar	Indicator	Indicator description	Source(s)
Impact	Land use change	Semi Natural Habitat Fraction	The Semi-Natural Habitat Fraction measures the percentage of a country's land area covered by natural and semi-natural habitats, meaning excluding artificial and agricultural lands, at the last year available from satellite-based land cover maps with very high resolution (10m). This metric is essential for evaluating the extent to which a country maintains its biodiversity and provides essential ecosystem services.	AXA Climate, Dynamic World
		Semi Natural Habitat Change	The Semi-Natural Habitat Change measures the trend of the percentage of a country's land area covered by natural and semi-natural habitats (excluding artificial and agricultural lands) for a four year range from the last year available. The land cover is computed thanks to satellite-based land cover maps at very high resolution (10m).	AXA Climate, Dynamic World
		Landscape Fragmentation	Landscape Fragmentation is evaluated by calculating the average coherence for each country on a 0.2° grid. The coherence metric corresponds to the probability that two individuals will be found within the same patch or area. It measures how natural and semi-natural habitats are divided into smaller, isolated patches due to human activities such as urbanisation, transportation infrastructure, and agricultural expansion. The fragmentation, caused by these activities, reduces the resilience of ecosystems and disrupts habitat connectivity, which is crucial for the movement and survival of many species.	AXA Climate, Dynamic World, Open Street Map
		Landscape Fragmentation Change	Landscape Fragmentation Change is evaluated by calculating the variation between the average coherence of a reference year to the one four years before for each country on a 0.2° grid.	AXA Climate, Dynamic World, Open Street Map
	Climate Change	GDP-Adjusted Carbon Footprint	GDP-Adjusted Carbon Footprint computes the deviation between consumed GHG emissions and the average emitting activity of countries with a similar level of income. Consumed GHG emissions are defined according to Partnership for Carbon. Accounting Financials (PCAF)'s standards, which includes territorial, and imported emissions and excludes exported emissions.	LSEG
		NDC Implied Temperature Rise	The NDC Implied Temperature Rise (ITR) estimates the potential level of global warming by 2100 if the whole world had the same carbon budget overshoot than a specific country. This country "overshoot" is defined as the gap between its 1.5°C-aligned carbon budget and the carbon budget induced by the emission target formalised in its Nationally Determined Contributions (NDC). If a country's 'NDC-based' projected emissions stay below its 1.5°C-carbon budget is called 'undershoot'; if its projected emissions are above	LSEG

Pillar	Sub-pillar	Indicator	Indicator description	Source(s)
			its Paris-aligned carbon budget, it's labelled 'overshoot'. To define the countries' carbon budget consistent with a 1.5°C objective (or 2°C), LSEG D&A developed the CLAIM methodology. The statistical approach is designed to remain as impartial as possible, given the politically sensitive nature of global carbon budget distribution. CLAIM incorporates a variety of parameters that can be considered to reflect the country's climate profile in comparison to others, such as GDP, energy intensity of the GDP, carbon intensity of the energy mix, past emissions, etc.	
	Pollution	Light Pollution	The Light Pollution indicator measures – thanks to the evaluation of yearly night lights using monthly grid data of mean cloud-free radiance (nW/cm2/sr) with satellite visible and infra-red data – the percentage of each country where light emissions are not considered to exceed the night sky and have little impact on wildlife (< 2 nW/cm2/sr [Hügli, 2021] [Widmer et al., 2022]).	AXA Climate, NASA (VIIRS)
		Pesticide Consumption	Pesticide Consumption (in kg/ha) reflects the environmental impacts of agricultural practices as excessive use of pesticide can notably lead to soil and water contamination, biodiversity loss, and potential health risks for both humans and wildlife.	FAO
		Fertilizer Consumption	Fertilizer consumption reflects the environmental impacts of agricultural practices as excessive use of fertilizers can notably lead to significant water pollution and impact wildlife. The fertilizer consumption indicator (kg/ha of arable land) includes nitrogen, potassium and phosphate fertilizers.	World Bank
		Solid Waste	Household solid waste in kg/capita/year as registered by the UE, OCDE or the UN database World of Waste. The most recent date available in these three sources is used for each country.	OCDE/Eurostats/UN
	Resource use deficit	Overshoot Days	Countries Overshoot Days calculates the date on which a country's consumption exceeds its available resources following the Global Footprint Network methodology. This date highlights the level of natural resource consumption in any given country each year.	Global Footprint Network
		Overshoot Days Change	The trajectory towards reducing the overuse of natural resources is computed by taking the average trend over the last five years of the number of days for which a country's consumption exceeds its available resources following the Global Footprint Network methodology.	Global Footprint Network
	Invasive Species	Invasive species	The number of present invasive species as declared by countries on GRIIS database is divided by the known richness of species in the country.	AXA Climate, GRIIS
Dependency	GDP dependence	Spatial Dependence	Spatial dependence is evaluated by taking the maximum grade of any ecosystem service category (Provisioning Services, Regulating and Supporting Services – Enabling, Regulating Services – Mitigating, Cultural Services) from the WWF Risk Filter's Physical Risk Assessment for each country and normalizing it by the highest possible grade.	WWF Risk Filter
		Sectoral Dependence	The GDP is broken down by major sector (agriculture/industry/services). The dependency score associated with these sectors by ISIC	AXA Climate, ENCORE, OCDE / World Bank

Pillar	Sub-pillar	Indicator	Indicator description	Source(s)
			category is calculated per category of ecosystem services and then the average is taken and weighted by GDP following: (GDP_agriculture * factor_encore_agri + GDP_industry * factor_encore_industry + GDP_services * factor_encore_services) / (GDP agriculture + industry + services)).	
	Physical risk exposure	Historical Physical Risk	Six climate hazards are used to build physical risks scores: heatwaves, droughts, water stress, intense precipitations, riverine floods, and coastal floods. For each hazard, raw climate data is analysed to calculate specific indicators that describe a hazard's frequency and/or intensity. Past exposures are computed from the absolute values of these indicators (e.g., the frequency of warm days). Since the impact on a given sector of the economy depends on this sector's vulnerability to the hazard, hazard scores are combined with the sector-specific vulnerability scores. These combined scores are linked to the sectoral Gross Domestic Product (GDP) breakdown, using a weighted average to obtain each hazard-specific risk scores for each country. Finally, a single, multi-hazard score summarises the country's overall physical climate risk level: this synthetic score is calculated by averaging the country's three highest hazard-specific scores.	LSEG
		Delta 2050 Physical Risk	Seven climate hazards are used to build physical risks scores: heatwaves, droughts, water stress, intense precipitations, riverine floods, coastal floods and increase in average temperature. For each hazard, raw climate data is analysed to calculate specific indicators that describe a hazard's frequency and/or intensity. Forward-looking exposure is defined by the change in climate conditions, calculating the difference between future and past climate indicators (e.g., additional warm days). Forward-looking data is based on the IPCC SSP5-8.5 climate scenario, following a 'hope for the best, plan for the worst' type of approach. Since the impact on a given sector of the economy depends on this sector's vulnerability to the hazard, hazard scores are combined with the sector-specific vulnerability scores. These combined scores are linked to the sectoral Gross Domestic Product (GDP) breakdown, using a weighted average to obtain each hazard-specific risk scores for each country. Finally, a single, multi-hazard score summarises the country's overall physical climate risk level: this synthetic score is calculated by averaging the country's three highest hazard-specific scores.	LSEG

Pillar	Sub-pillar	Indicator	Indicator description	Source(s)
Policy	Species protection	Threatened species and species protection	Species related policies can be appreciated following two different aspects: species with an associated threat level and species with a protection status. Threatened species are typically documented in red lists, notably thanks to IUCN efforts, and its compilation at the country level is vital for conservation efforts. On the other hand, species protection can be achieved through international conventions or national regulations. This indicator evaluates the number of species reported as threatened or protected at the country level, the extensiveness of reigns and taxa considered, data accessibility and recency, and the existence of dedicated laws. All this information is used for an overall assessment of a country's efforts (low / medium / high) in species monitoring and protection.	AXA Climate
	Protected Areas	Protected Areas Fraction	The Protected Areas Fraction measures the percentage of each country territory and marine areas which is effectively protected for nature-related purposes.	AXA Climate
	National Adaptation Plans	NBSAPs	Boolean indicator for countries with a National Biodiversity Strategies and Action Plans deposited at the United Nations.	United Nations
		NAPs	Boolean indicator for countries with a National Adaptation Plan (climate change focus) deposited at the United Nations.	United Nations

Appendix 3: Pillar scores

Country	Impact	Dependence	Policy
Argentina	0.35	0.52	0.64
Australia	0.55	0.49	0.86
Austria	0.55	0.59	0.90
Belgium	0.35	0.65	0.53
Brazil	0.59	0.41	0.61
Canada	0.42	0.75	0.79
Chile	0.44	0.37	0.58
China	0.39	0.37	0.77
Colombia	0.69	0.35	0.81
Croatia	0.55	0.64	0.58
Czechia	0.48	0.61	0.50
Denmark	0.42	0.42	0.71
Finland	0.61	0.54	0.43
France	0.69	0.81	0.84
Germany	0.58	0.61	0.75
Greece	0.57	0.53	0.48
Hong Kong	0.22	0.73	0.82
Hungary	0.67	0.46	0.73
India	0.55	0.14	0.44
Indonesia	0.46	0.22	0.61
Ireland	0.52	0.51	0.73
Israel	0.45	0.51	0.42
Italy	0.51	0.55	0.73
Japan	0.43	0.51	0.65
Luxembourg	0.44	0.92	0.83
Malaysia	0.44	0.20	0.48
Mexico	0.68	0.61	0.48
Netherlands	0.49	0.34	0.73
New-Zealand	0.31	0.62	0.49
Nigeria	0.75	0.06	0.18
Norway	0.42	0.67	0.67
Peru	0.67	0.25	0.67
Philippines	0.70	0.28	0.38
Poland	0.43	0.52	0.64
Portugal	0.61	0.73	0.44
Romania	0.67	0.50	0.51
Russia	0.42	0.67	0.47

Country	Impact	Dependence	Policy
Saudi Arabia	0.36	0.13	0.26
Singapore	0.49	0.62	0.43
Slovakia	0.36	0.70	0.70
Slovenia	0.51	0.73	0.65
South Africa	0.52	0.72	0.52
South Korea	0.39	0.58	0.67
Spain	0.70	0.74	0.76
Sri Lanka	0.61	0.22	0.37
Sweden	0.53	0.66	0.54
Switzerland	0.70	0.64	0.80
Taiwan	0.14	0.30	0.62
Thailand	0.56	0.42	0.67
Turkey	0.42	0.55	0.43
United Kingdom	0.58	0.76	0.51
United States	0.27	0.71	0.62
Vietnam	0.49	0.11	0.61

Source: AXA Climate and FTSE Russell.

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