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Climate & Nature Sovereign Index

Introducing a framework for a clear
assessment of environmental risk

July 2020





An important first step in
harnessing the potential of
sovereign debt investing
to help our planet's transition
towards sustainability

An important
harnessing the
sovereign debt

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Contents

Foreword	3
The fast view	5
Part one	
Why we created this index: an urgent need for solutions	10
Part two	
How the index works: approach and methodology	18
Part three	
What the index tells us: insights and implications	26
Conclusion and next steps	33
Appendix 1	
How the CNSI can complement, and challenge, ESG scores	35
Appendix 2	
Climate & Nature Sovereign Index: Indicators	36

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Foreword

Our relationship with the natural world is broken. The amount of planet-warming carbon dioxide in the air reached 417 parts per million in May 2020 – the highest it has ever been in human history. Impacts linked to human activity have significantly altered three-quarters of the land-based environment and about two-thirds of the marine environment. Furthermore, in the last 40-plus years, we have lost on average 60% of the populations of vertebrate animals.

This endless encroachment into the natural world is pushing our planet dangerously close to crossing a cascade of tipping points, such as runaway loss of ice sheets and forests. If breached, these tipping points will set in motion a series of irreversible changes in our climate system, leading to a hotter and eventually less hospitable world for people. Our destruction and conversion of natural habitats to meet our endless needs has also progressively increased the contact between humans, livestock and wildlife, leading to a rise in frequency and number of new zoonotic diseases with pandemic potential. As COVID-19 has shown us, such pandemics can lead to terrible social and economic costs. So, protecting nature is really about protecting people.

We still have a window – albeit a rapidly closing one – to act. Implementing urgent, deep and structural transformations that will help us heal our relationship with nature will be necessary for all countries – whose wealth is built upon their ‘endowment’ from nature – and hence also for investors lending to countries. In our 2019 ‘Satellites and Sustainability’ report,¹ we highlighted this critical role of sovereign debt investors in moving towards sustainable management of our natural resources. The report also underlined the potential for geospatial data and analysis to help investors identify trends in natural resource management and biodiversity conservation at the country level.

Through our latest work to develop a pilot ‘Climate and Nature Sovereign Index’- WWF and Ninety One (formerly Investec Asset Management) have gone a step further in our efforts to leverage the unique position and power of the sovereign debt asset class towards safeguarding nature. This index – all details and methodology are fully available upon request from the authors – is based on an innovative framework, which uses real-time and forward-looking indicators to assess long-term risks relating to climate change and nature loss at a country level. Such a framework should not only help achieve a more

1. <https://ninetyone.com/-/media/documents/insights/91-sustainability-and-satellites-white-paper-en.pdf>

robust integration of environmental risk in the sovereign debt asset class – estimated to reach over US\$50 trillion this year² – but also help countries in designing appropriate policy and institutional mechanisms that can make their borrowing more attractive and sustainable in the long term.

Employing the index in combination with new financing mechanisms would also help private and public sovereign debt investors to engage with countries in the post-COVID-19 recovery phase and help them transition to a sustainable trajectory that will make their investments more resilient to climate and nature-related and other risks alike.

To secure a happier, flourishing and sustainable future for ourselves and generations to come after us, we will need urgently to halt and reverse the loss of nature. To this end, WWF together with other NGOs, businesses and financial institutions is advocating for a New Deal for Nature and People that aims to protect and begin to restore nature by the end of the current decade. The stakeholders in the sovereign debt market will have an important role to play if we are to achieve this target. At Ninety One, we believe our purpose is to invest for a better tomorrow. That tomorrow will only be better if it is sustainable and makes a positive difference to people and the planet. Together, WWF and Ninety One hope that the 'Climate and Nature Sovereign Index' will serve as a foundation upon which all stakeholders can accelerate their efforts to safeguard our natural world and build the resilience of the global economy.



Tanya Steele
Chief Executive
WWF - UK



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Chief Executive Officer
Ninety One

2. <https://uk.reuters.com/article/uk-markets-global-debt/world-government-debt-to-hit-record-53-trillion-this-year-sp-global-idUKKBN20E2I5>. February 2020

The fast view

1. Addressing an urgent need

The natural world — the foundation of every nation's development and continued growth — is in steep decline, creating systemic risks for economies globally.

A broad group of stakeholders, especially investors and policymakers, urgently need a single, coherent framework through which to assess long-term climate and nature risk at a country level.

This would enable investors to integrate environmental factors into their overall risk management frameworks and investment decision-making processes. This, in turn, would strongly incentivise countries to establish environmentally responsible institutional and policy mechanisms in order to make inward investment and lending more attractive.

Such a framework will also go a long way to ensure that vast amounts of capital invested in sovereign bonds — estimated to surpass US\$50 trillion this year — contribute in the efforts to transition our planet to a sustainable pathway.

2. How the index works

Covering developed and emerging countries, the Climate & Nature Sovereign Index (CNSI) incorporates real-time data and forward-looking projections to the extent possible. Thanks to ongoing work in geospatial modelling and remote sensing, these are now obtainable and set to improve rapidly over time.

The index covers nature- and transition-risk exposures, as well as the climate risks traditionally measured in indices, and makes explicit the economic and financial links to them. We have focused on indicators based on modelling from the CMIP5 IPCC climate model ensemble,³ where relevant, avoiding indicators based on older climate models. This, together with the breadth and forward-looking nature of the index, makes the CNSI an innovative new addition to existing environmental risk approaches.

The application of the index extends beyond risk measurement. It could also help identify environmental investment opportunities offering the 'best' prospects: best in terms of the likely effect on environmental risk and on a country's future growth path, and in terms of the return potential for investors — all of which are interlinked.

3. The fifth phase of the Coupled Model Intercomparison Project.

3. What the index tells us

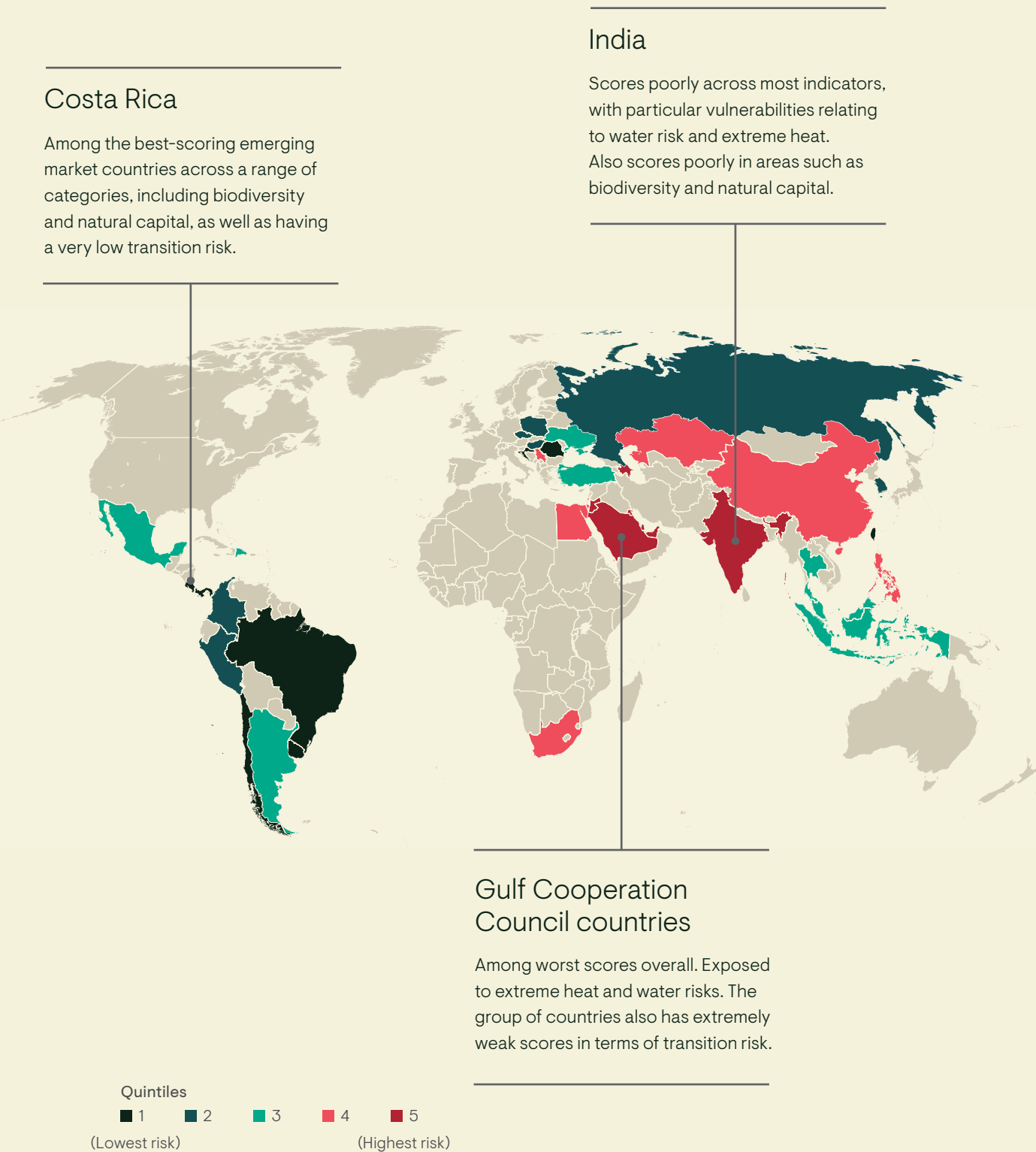
The CNSI highlights both where investment opportunities lie and where there is an urgent need for new financing solutions to be developed in bond markets. It also sheds new light on climate and nature exposures at the country level, in both developed and emerging markets.

India and the Gulf Cooperation Council countries stand out as overall most vulnerable across major emerging markets. India is exposed on almost all sub-categories, with particular vulnerabilities in terms of water risk, but also extreme heat. Even in areas such as biodiversity and natural capital, India is among the worst scoring countries. Unsurprisingly, Gulf Cooperation Council countries are also exposed to extreme heat and water risks, and this group also still posts extremely weak scores on transition risks. In contrast, Costa Rica is among the top-scoring emerging market countries across a range of categories, including biodiversity and natural capital, as well as having a very low transition risk. Other high performers such as Central and Eastern European countries and Uruguay also generally post low risk. However, even in those cases there remains room for improvement in certain areas.

Among developed markets, a general theme is the high exposure of Mediterranean countries in Europe, such as Greece, Cyprus and Portugal, which face significant exposure to water risk and rising atmospheric physical risk from higher temperatures. This highlights the importance of the European Green Deal and COVID-19 stimulus response, which needs to be carefully directed to address these emerging problems. Australia is understandably one of the most exposed developed markets from a transition risk perspective, ranking alongside many weaker emerging markets in this respect.

Based on the CNSI metrics, we note a number of potential opportunities and urgent issues that need to be addressed in bond markets. For instance, Chile has been an active early emerging market issuer in green bond markets. Given the physical risks (e.g. drought, pollution) in the country, such instruments could offer investors the chance to contribute to Chile's future sustainable growth. A number of other larger emerging markets have been discussing, and laying the groundwork for, green and Sustainable Development Goal bond issues. We believe the CNSI offers guidance on the areas that governments should prioritise in growing these markets.

Figure 1: Risk in emerging markets



We focus here on a subset of the emerging markets universe captured in the dataset. We analyse 38 countries which (i) are rated investment grade; and (ii) issue substantially in local currency sovereign markets; or (iii) make up a significant portion of emerging market hard-currency debt indices. Source: Ninety One and WWF, July 2020. For illustrative purposes only.

Figure 2: Risk in developed markets

US

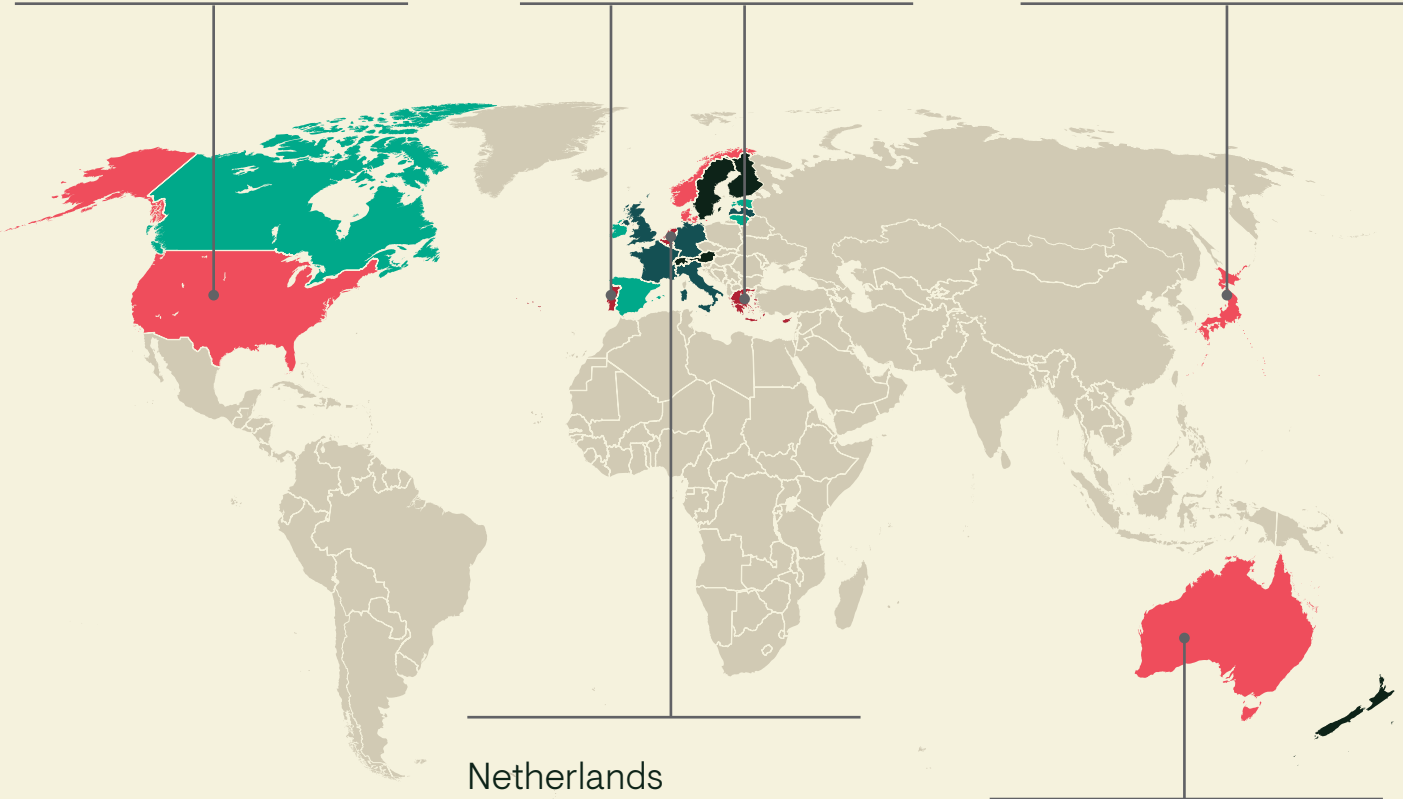
Very low levels of aggregate energy and carbon efficiency pose major long-term transition risks, with the tax base less environmentally aligned than any other developed market.

Greece and Portugal

Significant exposure to water risk and rising atmospheric physical risk from higher temperatures. European Green Deal and COVID-19 stimulus response will be vital.

Japan

Among developed markets, Japan is more exposed to increased atmospheric volatility in heat and incidence of major disasters.



Netherlands

Scores poorly in terms of sea level and coastal risk.

Australia

Highly exposed from a transition risk perspective, ranking alongside many weaker emerging markets in this respect.



Source: Ninety One and WWF, July 2020. For illustrative purposes only.

Defining nature

Natural capital

This is the Earth's stock of renewable and non-renewable resources (e.g. ecosystems and the habitats and species they contain, water, soils, minerals and the atmosphere) that combine to yield a flow of services that benefit people⁴.

Ecosystem services

Services provided by ecosystems include, for example: the provision of food, timber and fibre; purification of water; pollination of crops; protection from flooding and erosion; and regulation of the climate through absorption of carbon. These services can provide economic, social, environmental, cultural, spiritual and well-being benefits. The value of these benefits can be understood in qualitative or quantitative terms (e.g. in economic terms) depending on context⁵.

Biodiversity

This captures the variety of life on Earth. It is most commonly measured in species richness — the total number of species in an area — with the tropics having a higher number of species than temperate regions. Biodiversity also includes the genetic variety within species and the variety of ecosystems that species create⁶. Nature provides a wide range of economic, social, environmental, cultural, spiritual and well-being benefits to people.

In this report, and for the index, we use the word 'nature' to cover all of the above concepts and terms. Similarly, 'environmental risk' – the broad umbrella term used by the investment industry – covers all risks relating to climate change and nature loss.

Nature and climate are inextricably linked. A continuing loss of nature negatively affects a country's ability to mitigate the impacts of climate change (e.g. mangroves provide protection from storm surges) and absorb and store carbon (e.g. in peatlands and forests). Furthermore, climate change contributes to the loss and shifting of habitats and species (e.g. through increased wildfires or loss of coral reefs).

4. The Dasgupta Review – Independent Review on the Economics of Biodiversity, Interim Report, April 2020. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/882222/The_Economics_of_Biodiversity_The_Dasgupta_Review_Interim_Report.pdf

5. Ibid.

6. Encyclopedia Britannica. <https://www.britannica.com/science/biodiversity>

An aerial photograph of a dry lake bed. The landscape is a mix of reddish-brown, tan, and grey earth, showing signs of erosion and dryness. Several pools of bright blue water are scattered across the terrain, particularly in the upper half of the image. The overall scene conveys a sense of environmental degradation or drought.

Part one

Why we created
this index: an urgent
need for solutions

The natural world is in decline

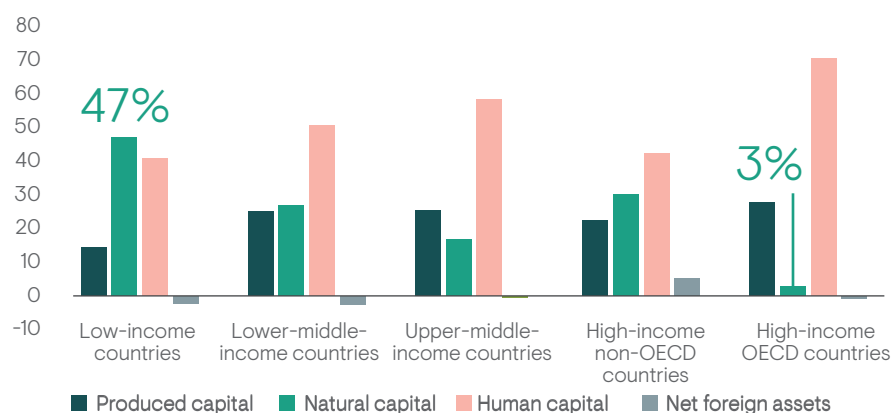
The natural world sustains all life on the planet. It provides us with food, water, medicines and ecosystem services that regulate air quality, climate and nutrient cycles; and is a source of spiritual, aesthetic and recreational nourishment.

Nature — and the natural capital and ecosystem services it provides — are in steep decline. Ever-increasing demand for natural resources has accelerated extinction rates by at least 10 times, and possibly hundreds of times, relative to the average of the past 10 million years⁷. Between 1970 and 2014, human activity caused a 60% reduction in populations of mammals, birds, fish, reptiles and amphibians⁸. Our natural ecosystems, which rely on biodiversity for their resilience, are facing unprecedented degradation. We have lost about half of the planet's shallow-water corals in the past three decades; over one-fifth of the Amazon rainforest has disappeared in the last 50 years. The deterioration of biodiversity is strongly linked to climate change: the warming of the planet stresses ecosystems, changing habitats and lifecycles⁹.

The foundation of the wealth of nations

The natural assets within each nation's borders vary enormously, but they are the foundation of all countries' development and continued growth. For low-income countries, wealth accumulated from the transformation of natural assets enables them to move beyond subsistence production of food and shelter to manufacturing and services. This process is illustrated by the fact that natural capital constitutes 47% of the wealth in low-income countries (the largest single component of wealth), but only 3% of the wealth of high-income OECD countries (2014 data). Put another way, many low-income countries still possess much of the natural wealth the planet endowed them with — highlighting the need to assist them to develop differently from the destructive path pursued historically by many developed nations.

Figure 1: Natural capital as a percentage of country wealth



Source: World Bank calculations. <https://openknowledge.worldbank.org/bitstream/handle/10986/29001/9781464810466.pdf?sequence=4&isAllowed=y>

7. <https://ipbes.net/news/global-assessment-summary-policymakers-final-version-now-available>

8. <https://www.worldwildlife.org/pages/living-planet-report-2018>

9. <https://www.cbd.int/climate/intro.shtml>

Traditional theories of economic growth regard manufactured and human capital as the only necessary elements to generate additional capital, in the form of goods and services^{10,11}. In reality, natural assets are central to economic growth in rich and poor countries alike — dispelling the notion that development is about the endless liquidation of natural assets to obtain other higher-value assets. Land is required for all economic activity, natural materials are needed to form commodities, and energy is needed to drive production processes and the exchange of commodities. The obvious implication is that risks to nature are systemic: if nature fails, the knock-on effects can be severe. Poorer nations typically bear the brunt, but wealthy countries are by no means immune, with impacts quickly cascading through interconnected financial markets and global systems.

The value of natural capital may be low in OECD countries relative to total wealth, but on a per capita basis natural capital's value in wealthy countries is three times that in low-income countries¹². The way a country manages its natural assets has a significant bearing on its long-term growth. Sustainable management of renewable resources and prudent use of resource-rents from non-renewables have been seen as the foundations on which a country can build a portfolio of other assets, including produced and human capital, to increase economic productivity and increase long-term resilience. All countries, developed and emerging, need to develop holistic and fully financed transition strategies to ensure the use of resource rents from non-renewables declines over time, in line with their commitments under the Paris Climate Agreement.

Investors' focus on environmental factors continues to increase. Disclosure of Scope 3 emissions¹³ and portfolio temperature-scoring, for example, are likely to become widespread, enabling deeper analysis of sustainability considerations related to climate. Countries that can demonstrate effective natural-capital management should enjoy lower borrowing costs and increased inflows into their government bonds, since a more sustainable economic growth path translates to lower risk for bond investors. The most progressive countries will permanently embed environmental factors into their monetary and fiscal policies and see the environment as inexorably linked to future prosperity.

The way a country manages its natural assets has a significant bearing on its long-term growth

10. Vivek Anand Voora and Henry David Venem, International Institute for Sustainable Development, "The Natural Capital Approach". https://www.iisd.org/pdf/2008/natural_capital_approach.pdf

11. England, Richard W. "Natural capital and the theory of economic growth." (2000). https://www.researchgate.net/publication/222654061_Natural_capital_and_the_theory_of_economic_growth

12. Natural Capital, Natural Capital Coalition. <https://naturalcapitalcoalition.org/natural-capital-2/>

13. 'Total lifecycle' indirect emissions associated with an economic activity, including in the supply chain, during use of a product and at disposal.

An urgent need for a unified nature-related risk framework

A broad group of stakeholders, including investors and policymakers, urgently need a single, coherent framework through which to assess long-term climate and nature risk at a country level. This would enable investors to integrate environmental factors into their overall risk management frameworks and investment decision-making processes. This, in turn, would strongly incentivise countries to establish environmentally responsible institutional and policy mechanisms in order to make inward investment and lending more attractive. Such a framework will also go a long way to ensure that vast amounts of capital invested in sovereign bonds — estimated to surpass US\$50 trillion this year¹⁴ — contribute in the efforts to transition our planet to a sustainable pathway.

We acknowledge that the possible flip-side of a framework that encourages positive policy responses by influencing investment decisions is that it could drive capital away from low-ranking nations (i.e. those at high risk). A sustainable financial system therefore requires accompanying policies and mechanisms to mitigate this risk, as discussed later in this report. We are by no means advocating a position that starves nations of needed short-term capital; rather, this framework should allow the better integration of nature, climate, and economy over the medium and long run. In fact, we believe that addressing these issues should lead to higher returns in these higher risk countries, i.e. by creating environmental investment opportunities that offer compelling prospects in terms of the likely effect on environmental risk; impact on a country's future growth path; and return potential for investors. Similarly, the index can help channel sustainability driven investments (e.g. via green bond issuance) to those countries in greatest need.

Done right and managed correctly, this framework could enable all stakeholders to contribute to the ultimate objective of protecting the natural world and avoiding the severe economic and human consequences of failing to do so. We detail on the opposite page some of the key stakeholders and how they could use such a framework.

14. <https://uk.reuters.com/article/uk-markets-global-debt/world-government-debt-to-hit-record-53-trillion-this-year-sp-global-idUKKBN20E2I5>. February 2020

How a unified nature-related risk framework could help multiple stakeholders to contribute to the ultimate objective of protecting the natural world

Countries

To attract investments and safeguard the natural world, and hence sustain economic growth in the long term.

Rating agencies

To develop a more comprehensive view on sovereign risks by integrating factors related to climate change and nature loss into the rating process.

Sovereign debt investors

To improve the long-term resilience of their portfolios and identify areas for investments in natural capital.

Equity investors

To better assess risk by overlaying country-level macro views on company-level micro assessments to identify commercial risks and opportunities.

International financial institutions and donors

To identify impact-based interventions that foster countries' long-term transition to a sustainable economic pathway.

To highlight which countries are likely to find it harder to secure investment/borrow, and hence most need alternative sources of finance to support conservation.

A vital consideration for investors

Among investors specifically, the relationship between a country's natural resources and its economic performance is especially material to holders of sovereign debt, as we discussed in our 2019 paper *Sustainability and Satellites*¹⁵. This is because natural-capital management influences 'sovereign health' — a country's capacity to issue and repay debt¹⁶. Careful stewardship of natural resources can improve a country's ability to sustain revenues; conversely, growth at the expense of widespread natural degradation can have high economic and social costs.

For sovereign debt investors, a clear assessment of current and future dimensions of environmental sustainability and risk on a country-by-country basis is invaluable. But it is also crucial for other investors — including those focused on the corporate sector — because it is impossible to gauge wider company-level environmental risk exposure in frameworks such as the Task Force on Climate-related Financial Disclosures (TCFD) or the Bank of England stress tests. This is because individual company risks can be overwhelmed by broader risks to inputs, fixed assets and markets, and by sovereign financing shocks. As COVID-19 has highlighted so vividly, almost all financial markets are vulnerable to shocks arising from natural events.

Real-time and forward-looking measurement

To be useful to all of the stakeholders discussed above, a framework to assess long-term climate and nature risk requires real-time and forward-looking measurement of climate change and loss of nature at the country level. Thanks to ongoing work in geospatial modelling and remote sensing — outlined on page 21 — these are now increasingly obtainable, removing a key barrier and prompting us to create the index we discuss in the next section.

15. <https://ninetyone.com/-/media/documents/insights/91-sustainability-and-satellites-white-paper-en.pdf>

16. Planet Tracker and London School of Economics, 2020. <http://www.lse.ac.uk/granthaminstitute/publication/the-sovereign-transition-to-sustainability-understanding-the-dependence-of-sovereign-debt-on-nature/>

Policies and mechanisms for directing capital to where it is needed the most

Alongside a coherent framework through which to assess long-term climate and nature risk at a country level, investors and policymakers also require financial mechanisms to steer capital towards where it is needed most. This includes investments in natural assets to deliver the biggest economic and social benefits — and by working in partnership with official development financing institutions to create some new funding instruments.

Such instruments must both address immediate liquidity requirements of sovereigns and ensure prudent management of natural resources so that debt is sustainable in the long term. The following are some potential novel sovereign bond models that could achieve a ‘win-win-win’: for sovereigns, sovereign debt investors and the natural world.

Sustainable Development Goal bond fund

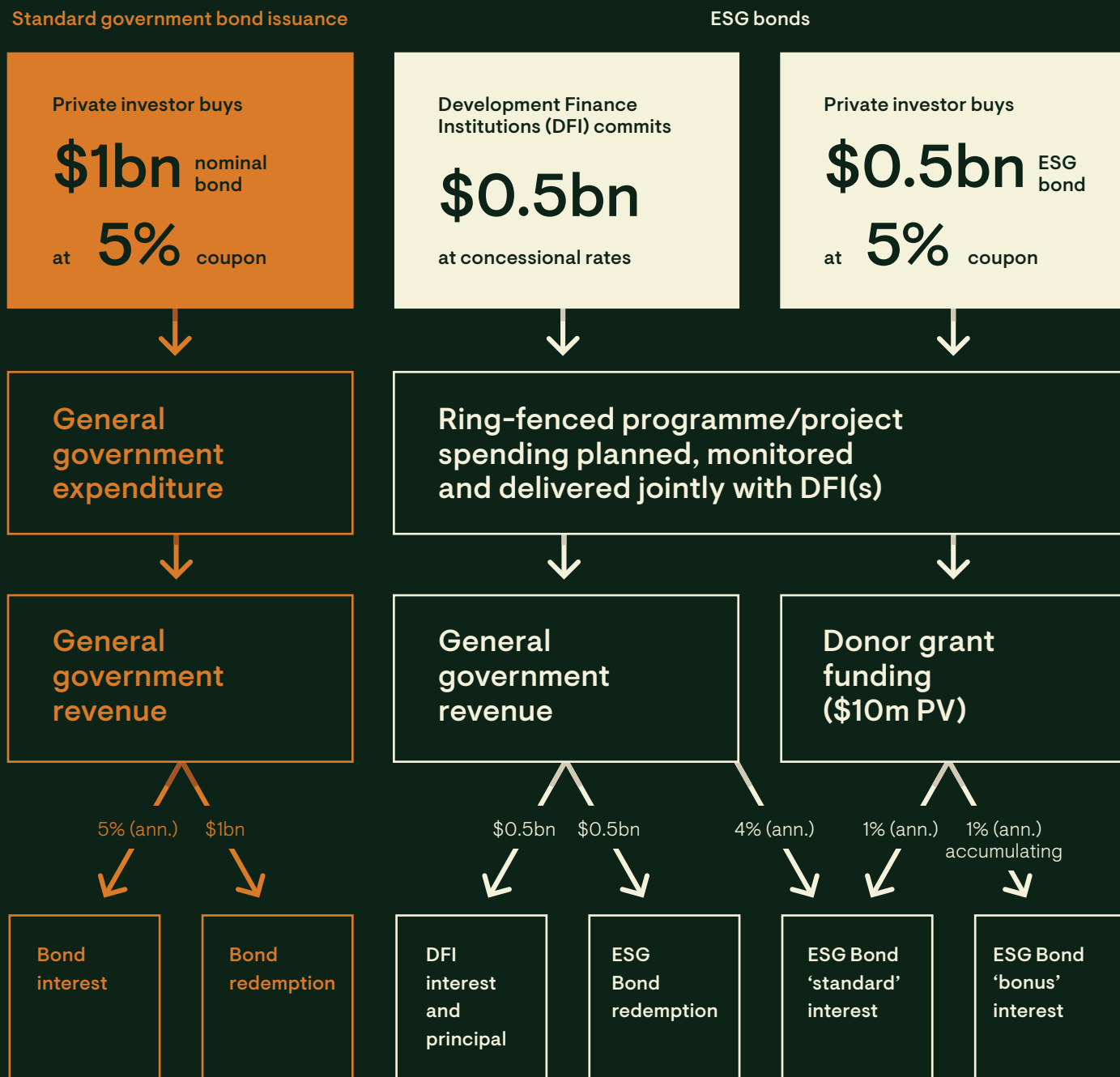
An International Financial Institution (IFI)-supported Sustainable Development Goal bond fund (SDG Fund) would be similar to the IFC Emerging Markets Green Bond fund launched in 2018, focused on buying SDG bonds in the primary market. An equity/junior tranche of capital from an IFI allows private creditors to achieve a material credit uplift on the underlying bonds, helping to attract a broader base of capital to emerging market sovereign financing while lowering the interest costs for countries. SDG bonds, designed in line with ICMA Sustainable bond guidelines, can help to raise the sustainable growth impact of spending. The SDG Fund could include features that support long-term market development, such as capacity training to ensure high quality SDG bond design and issuance.

ESG-based ring-fenced IFI co-lending bonds

This structure can combine the efforts of private and public sector creditors to support a sovereign’s transition to a sustainable pathway. It encourages sovereigns to direct specific savings and macro-prudential buffers generated in the lending process towards investment in sustainability (though they can be ‘admin-heavy’ and relatively expensive in this model).

In this structure, an IFI identifies a project and commits a part of the required funding at a concessional rate; the remaining funding is secured from private creditors through an ESG bond. The IFI engages with the government to plan, monitor and deliver the ring-fenced funding. If the project milestones are achieved, a grant funding from the donor contributes part of the coupon on the ESG bond, hence lowering borrowing costs for the government. If the project fails to achieve its milestones, donor funding is suspended leading to original (high) costs of borrowing for the government (please see Figure 3).

Figure 3: Standard government bond issuance vs. co-lending ESG Bonds (a type of SDG bond with a co-lending component)



- i. Development Finance Institution identifies project and commits \$0.5bn with ESG bond issued for \$0.5bn to complete \$1bn.
- ii. Development Finance Institution monitoring of project/ring-fenced spending, while on track government pays 4%ar of interest while donor funding covers additional 1%, lowering government financing cost.
- iii. Donor contributes additional 1%ar (accrual SPV) for ESG bond investor which is released upon project completion. Bond redemption paid at maturity from government revenue.
- iv. If project/programme is not achieving milestones, donor funding is suspended, government reverts to paying 5% interest cost, ESG investor does not accrue additional upside returns.

Part two

How the index works: approach and methodology

How the index works: approach and methodology

A climate and nature risk framework that could enable various stakeholders to help realise the ultimate objective of safeguarding our natural world would require detailed modelling. But until a broad coalition forms to undertake this, we believe a cross-country Climate and Nature Sovereign Index (CNSI) offers an initial solution.

To this end, we propose a framework that combines the economic and financial factors that currently inform risk-modelling for sovereign debt investments, and the risks related to natural capital and climate change. The resulting indicators, which are as real-time and forward-looking as possible, are then used to construct an index that facilitates cross-country comparison. We believe this index will evolve and improve over time and could be used by various stakeholders to help realise the ultimate objective of safeguarding our natural world.

The index requires a different approach to that used to construct current environmental risk indices. To maximise its usefulness to a broad range of stakeholders and build towards fully fledged economic modelling, the index incorporates real-time data and forward-looking projections. Thanks to ongoing work in geospatial modelling and remote sensing (please see page 21), these are now obtainable. For the CNSI, we have focused on indicators based on modelling from the CMIP5 IPCC climate model ensemble,¹⁷ where relevant, avoiding indicators based on older climate models.

The CNSI is complementary to policy-oriented indices such as the Yale Environmental Performance Index¹⁸. We propose a greater breadth of economic and financial indicators than that benchmark, so that the index reflects the factors that are material for investors, especially fixed income investors.

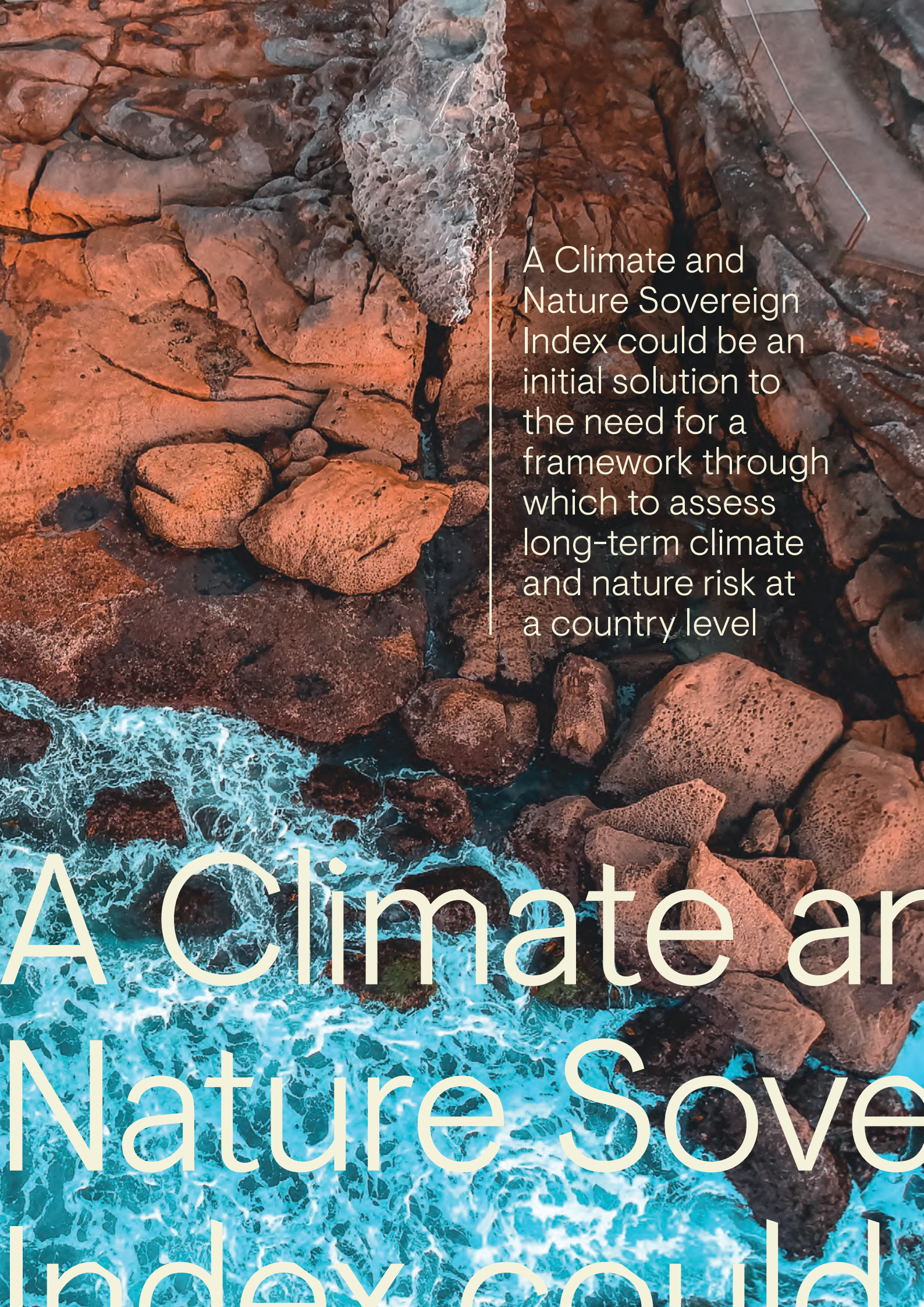
Further work can be done over time to assess the relevance of indicators and evolve the index constituents. The aim of the index governance would be to adapt the index over time as science-based input identifies potential improvements.

Climate and Nature Sovereign Index in a nutshell

- Uses real-time and forward-looking projections, wherever possible.
- Covers nature-capital and transition-risk exposures, as well as the climate risks traditionally measured in indices.
- Makes explicit the economic and financial linkages, with the aim of making the index useful to investors and policymakers, and employs a taxonomy aligned to investors' needs:
 - Biodiversity and natural capital
 - Physical risk (atmosphere, water and agriculture)
 - Transition risk
 - Financial and socio-economic resilience.

17. The fifth phase of the Coupled Model Intercomparison Project.

18. epi.yale.edu



A Climate and Nature Sovereign Index could be an initial solution to the need for a framework through which to assess long-term climate and nature risk at a country level

A Climate and Nature Sovereign Index could

Data advances: a tipping point for sustainability

It is often assumed that there is a lack of usable ‘environmental’ and ‘climate’ data for use in the financial sector, particularly around the issue of sovereign debt. While true to some extent, this is rapidly changing with the emerging adoption of novel spatial data approaches within the financial sector combined with a boom in new satellites and machine learning, which are opening new possibilities for the generation of timely and consistent global datasets. At the same time, advances in integrated environment-economic modelling are making it possible to better understand the impacts of environmental degradation on macro-economic outcomes, such as GDP growth rates (please see WWF’s Global Futures Report¹⁹ for more on this topic).

Broadly speaking, there are two major spatial data types relevant to this space: discrete and continuous. Continuous datasets are often generated using vast volumes of satellite imagery. With open imagery archives going back to the 1980’s, a significant data portfolio already exists, from ground carbon, to atmospheric pollutants, with multiple high-profile platforms providing open data online. For example, Global Forest Watch provides annual global scale updates on forest loss and weekly updates on extent of forest loss for the tropics, while Global Fishing Watch provides insights into the density of fishing activity. Discrete datasets, often generated more manually, help define the location of protected areas, endangered species ranges, etc. and continue to be developed and refined.

With the increase in satellites, better computers and machine learning, we can expect the portfolio of data to expand further still. In the next couple of years, a wide range of open and commercial global datasets are scheduled on relevant topics such as global oil spills, shipping activity, surface water change, agricultural performance, land cover change, biodiversity, and heatwaves. These datasets — with ever increasing temporal and visual resolution — will potentially be of high value and interest to actors considering the current and future environmental health and climate exposure of nations.

The spatial global datasets sovereign debt investors could draw upon for environmental and climate variables are then wide and increasing. These datasets can be considered alone or in combination, to create indicators. Spatial data defining the extent of countries’ protected areas is useful and provides insights into the broad priorities of a nation, alignment to SDGs etc. It provides additional insights into the environmental health of nations when compared against other datasets — highlighting month-on-month changes within protected areas (e.g. changes in mining activity and forest loss).

19. <https://www.wwf.org.uk/globalfutures>

The issue then is not so much a lack of data but confusion over which data to use, what data products to create and confidence in the approach. In short, inputs need to be benchmarked and robust methods and standards established. There must be consistency across the indicators used. For example, any climate scenarios used should be the same across different indicators and ideally comparable datasets should be used year on year, allowing direct comparison over time. This last issue is particularly problematic, where often datasets within the environmental and climate space are generated as one-offs, irregularly, or updated into a non-comparable form as the science evolves. To resolve this, trade-offs are likely to have to be made; rather than switching between cutting edge models, any robust measure consistently applied is perhaps of greater use. To ensure temporal consistency it is likely that users in some cases will need to generate their own results based on existing open data and code.

Ideally, data should be captured, analysed (and in many cases generated) by major business intelligence providers, who are well positioned to provide such a service to the finance sector

Arguably, it makes little sense for all sovereign debt investors to struggle with volumes of diverse datasets, analyse data and design different frameworks all to ultimately create a single spreadsheet. Ideally, data should be captured, analysed (and in many cases generated) by major business intelligence providers, who are well positioned to provide such a service to the finance sector. Indeed, many of the data requirements of the sovereign debt community align to the same data needs of wider applications of spatial finance. One can easily imagine the same system providing data cut to different scales of application, in this instance we summed at a national scale level to meet sovereign debt investors requirements, thus widening the business case as to why business intelligence providers might develop such a product line.

Within this report we have highlighted several useful environmental measures. These should not be considered as fixed but rather as flexible. This index, or anything like it, will need to go through a period of iterative development. Specifically within the environmental data space there are many other potential measurements we could have included, such as the IBAT datasets²⁰, differing land cover measurements, species data, etc.

Moving forward, to simplify the task for data providers and the wider financial community there is a clear role for the conservation sector to create and refine its datasets to provide national scale indicators with high temporal frequency. It is also vital these indicators are set against a clear baseline, which define the prior environmental status of a nation, enabling ongoing comparison to a fixed history rather than a moving target. Due to the importance of the topic, applicable for sovereign debt and wider spatial finance, WWF will continue to encourage financial institutions, intelligence providers and conservation data providers to develop resolutions, both from a data science and legal perspective.

20. ibat-alliance.org

The CNSI builds on the work of ND-Gain and Moody's, among others, enhancing the set of indicators used to increase the index's applicability to portfolio risk assessment. It facilitates cross-country comparisons and allows for assessment of companies' exposures to risks in their physical sources of production and demand. The index also enables the direct scoring from an environmental risk perspective of sovereign assets within portfolios.

The proposed set of indicators (shown in full in the Appendix) is designed to capture overall economic and financial channels of exposure to physical and transition risks arising from climate, biodiversity and natural-capital deterioration. As mentioned earlier, indicators are chosen to be real-time or forward-looking wherever possible, and to reflect the full breadth of economic and financial impacts that will need to be developed in subsequent country-level economic modelling.

Given the inherent uncertainty of measurements of environmental risk, especially future projections, we have taken an ensemble approach to index construction in two dimensions. First, from underlying data sources built on statistical models, we have combined various different models using a full range of climate scenarios. Second, we have included more than one approach to measuring certain key environmental risk channels, such as heat and drought, to try to reduce uncertainty through model averaging. We outline the set of indicators included in the index below, grouped into the four components of the CNSI (full details can be found in the Appendix):

Biodiversity and natural capital

- Degradation and/or depletion of natural capital (e.g., ecosystems such as forests, grasslands, wetlands and coral reefs, and fish stocks) and associated changes to ecosystem services, such as food and water supply, pollination, coastal protection and carbon sequestration
- Level and trends of loss of natural capital, including real-time deforestation data
- Data on level and trends of protection of ecosystems and biomes (terrestrial and marine)
- Future economic impacts due to natural-capital degradation and/or depletion (e.g. changes to GDP).

Physical risks (chronic and acute)

- Atmospheric – current trends and projected impacts of acute climate events and long-term global warming, such as droughts
- Water – acute risks from flooding, chronic risks from sea level changes and impacts on groundwater
- Agriculture – risks to food-production capacity.

Transition risks

- Energy production and exports that will likely come under pressure as measures to stop global warming intensify²¹.
- Capacity to adapt to positive trends in decarbonisation; ecosystem preservation.

Financial and socio-economic resilience

- Resilience in sovereign credit rating; fiscal space
- Resilience in balance of payments and FX reserves
- Resilience in existing socio-economics outcomes; e.g., health.

Here, we describe key features of the methodology used to calculate the index and weight various inputs, as well as the rationale for adopting this approach.

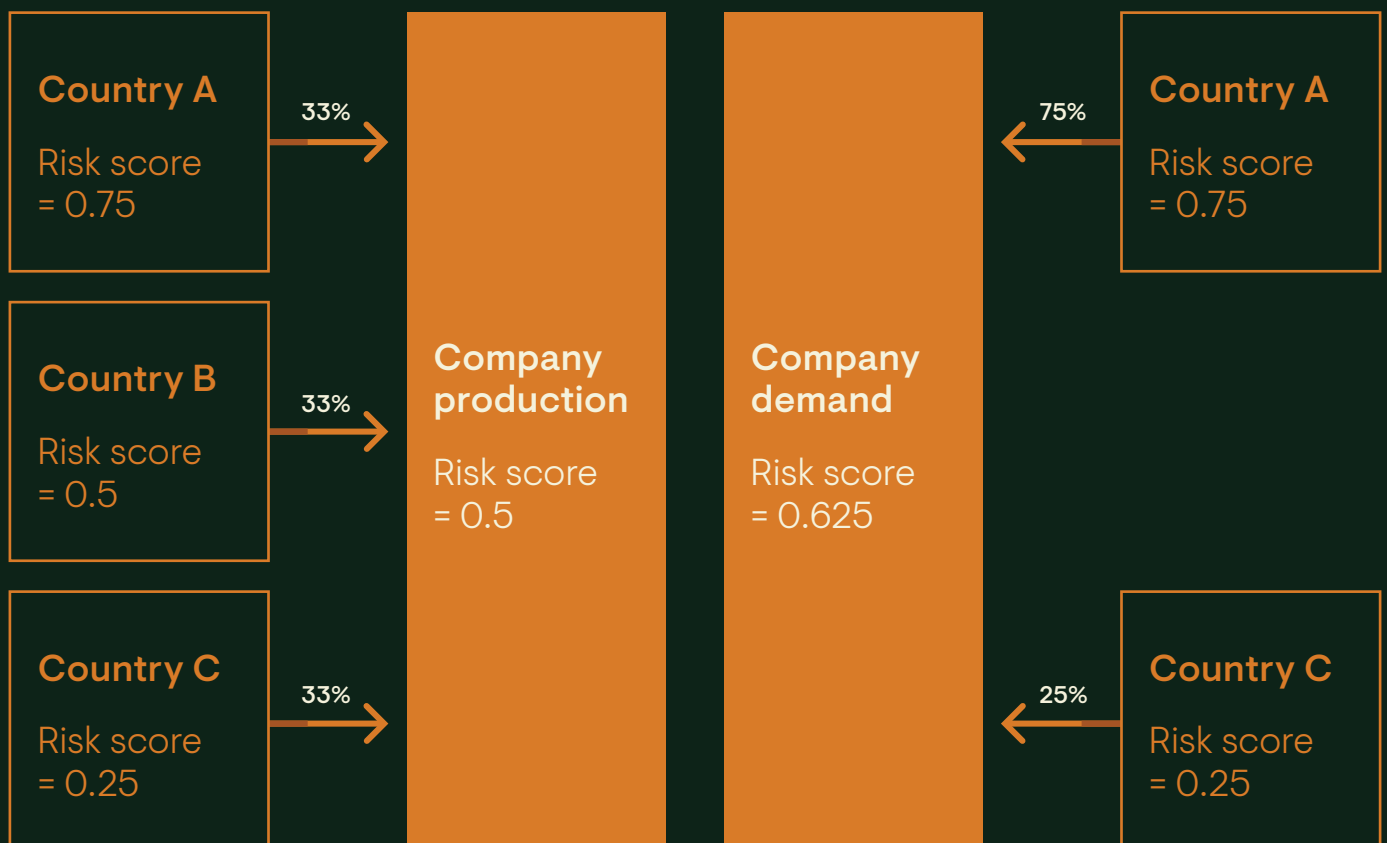
- 1. Materiality is embedded in the index calculation** — Two countries with minimal exposure to a particular risk should both score close to one for that measure. Hence, a cross-sectional standardisation, scaled 0-1, will be taken from each metric. All indicators are transformed such that 1 reflects minimum risk and 0 reflects maximum risk.
- 2. Outliers are retained** — Given the non-linear impacts and costs (loss and adaptation) of climate and nature risks, outliers will be retained to capture countries that face extreme tail risk from one or more factors.
- 3. All measures are scaled relative to a base, where possible** — e.g. GDP or total revenue – this will allow for cross-country comparability.
- 4. Approximately equal numbers of indicators are used across the different sub-components of the index** — This helps to avoid further complexity in terms of arbitrarily determining country-by-country materiality.
- 5. A geometric mean²² is applied in each subcomponent and across the overall index as a whole** — this approach reflects the importance of non-linearities in environmental risks. Geometric means penalise countries with a similar simple arithmetic mean to another country but greater dispersion. The rationale here is that one or two very weak scores suggest particularly acute risk, which should carry a higher weight.

21. <https://www.unpri.org/inevitable-policy-response/the-inevitable-policy-response-policy-forecasts/4849.article>

22. <https://mathworld.wolfram.com/PowerMean.html>

Using the CNSI in equity or corporate bond portfolio analysis

A direct score can be obtained for a portfolio's sovereign-asset exposure as a weighted sum. It should be duration-adjusted to reflect greater long-term risks from both physical and transition risks, which are non-linear over time²³. For corporate exposures, Bloomberg functionality, mapping country-level production and revenue mixes, can be used to create a spatially weighted measure of each corporate's production and revenue risks, as illustrated below.



Source Ninety One. For illustrative purposes only.

At present, complexities and interactions (as well as non-linearities and feedback loops) present difficulties in determining which factors will have a greater impact on a company's production and demand risks. For example, a manufacturer in a country with high physical or transition risks in the agricultural sector may appear initially to have low environmental risk exposure. However, over the long run that company may face impacts from indirect environmental-risk channels, such as significant increases in taxes or sovereign funding risks. Companies based in countries with poor energy grid mixes will have to declare this under the Task Force on Climate-related Financial Disclosures (TCFD), again creating new risks for companies that initially appear only moderately exposed.

Hence the CNSI should only be applied uniformly as a measure of production and demand risk as a first-stage application.

23. Further work will be required on a country-by-country basis to look at the temporal distribution of risks and potential tipping points, both in the underlying macroeconomic outcomes and in financing (e.g., sudden stops and climate insolvency).

Part three

Part three

What the index tells us: insights and implications

What the index tells us: insights and implications

India and the Gulf Cooperation Council countries stand out as most vulnerable overall across major emerging markets. India is exposed on almost all sub-categories, with particular vulnerabilities in terms of water risk, but also extreme heat. Even in areas such as biodiversity and natural capital, India is among the worst scoring countries. Unsurprisingly, Gulf Cooperation Council countries are also exposed to extreme heat and water risks, and this group also still posts extremely weak scores on transition risks.

In contrast, Costa Rica stands out as being among the top-scoring emerging market countries across a range of categories, including biodiversity and natural capital, as well as having a very low transition risk. Other high performers such as Central and Eastern European countries and Uruguay also generally post low risk. However, even in those cases there remains room for improvement. For instance, Uruguay shows specific weaknesses in biodiversity and natural capital, such as future growth exposure to loss of coastal biomes.

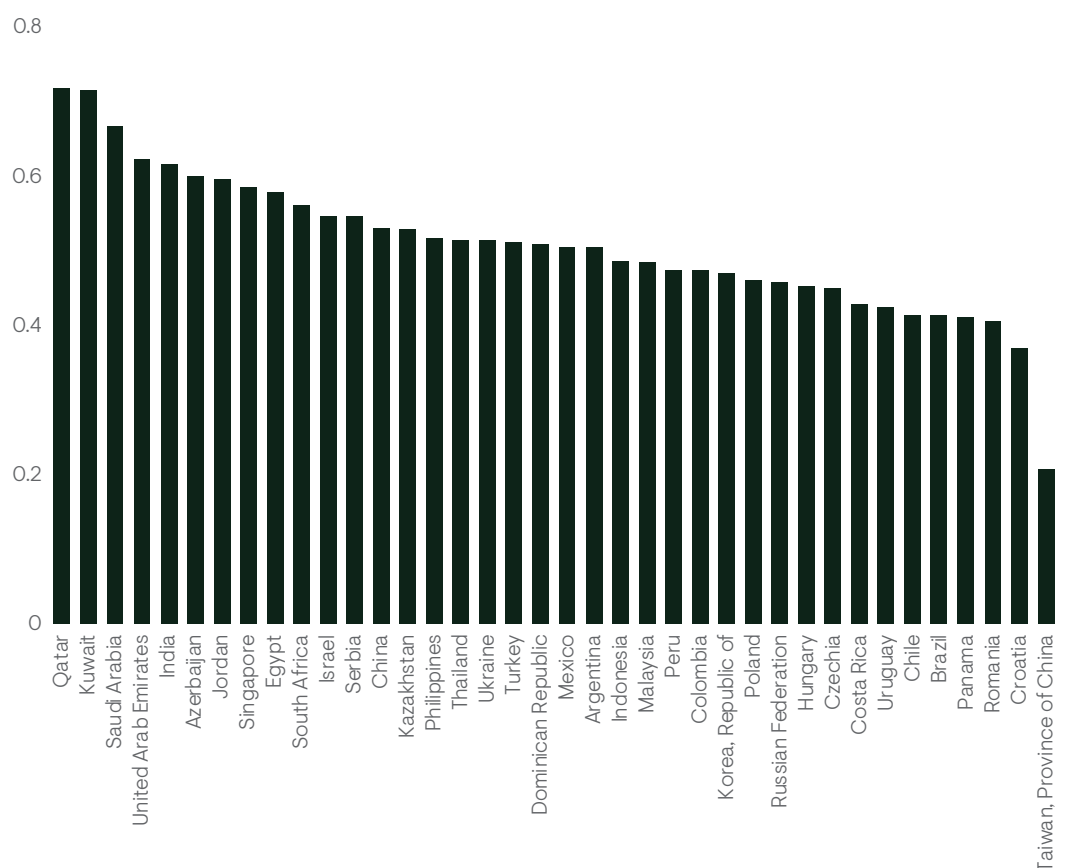
In developed markets, a general theme is the high exposure of Mediterranean countries in Europe, such as Cyprus, Greece and Portugal, to water risk and rising atmospheric physical risk from higher temperatures. This highlights the importance of the European Green Deal and COVID-19 stimulus response, which needs to be carefully directed to address these emerging problems. Australia is understandably the most exposed developed market from a transition risk perspective, ranking alongside many weaker emerging markets in this respect.

Emerging markets

We focus here on a subset of the emerging markets universe captured in the dataset. We analyse 38 countries which (i) are rated investment grade; and (ii) issue substantially in local currency sovereign markets; or (iii) make up a significant portion of emerging market hard-currency debt indices. Our main findings are:

- Outside of frontier markets and Sub-Saharan Africa in particular, risk cases are concentrated in Gulf Cooperation Council countries and Southern Asia. Some ex-Commonwealth of Independent States (CIS) countries²⁴ also show high risk.
- Countries with dedicated environmental agencies, strong legal frameworks and joined up policy across government (such as Chile, Taiwan, Uruguay and Costa Rica) demonstrate much lower forward-looking environmental risk.
- In central European markets (including Russia), specific weaknesses are offset by the much less negative implications of atmospheric and agricultural physical-risk trends in that region.

Emerging markets: overall risk (highest to lowest risk)



Source: Ninety One, June 2020. While the CNSI works on a scale of 0-1 with zero being highest risk and 1 being lowest, for visual representation scores were subtracted from 1 for the above chart.

24. Comprises Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, and Uzbekistan.

Sub-component index results – emerging markets



Biodiversity and natural capital

Greater biodiversity risk is strongly associated with countries with significant primary industries; this shows up in both current and forward-looking projections.

Countries with strong institutions and active policies such as Costa Rica, Panama and several countries in Central and Eastern Europe all score well with limited risk.

The high-risk measure for India stems primarily from the very severe risk the country faces from the deterioration in ecosystems due to water-asset decline as discussed in a 2019 WWF report²⁵.

Turkey and Uruguay score poorly on limited formal protection for key biomes.

Unsurprisingly, Gulf Cooperation Council countries with minimal natural-capital endowments have limited risk, but also very little opportunity for improvements via policy or investment.



Physical risk – atmospheric

Gulf Cooperation Council countries are among the most at risk from physical atmospheric risks, given their proximity to thresholds for economically feasible temperatures.

Some parts of Southern Asia face this risk, particularly India²⁶.

China and Turkey score poorly, given exposure to drought and associated economic losses.



Physical risk – water

Unsurprisingly, Gulf Cooperation Council countries appear among the most exposed to broad water risks.

China and Thailand also exhibit significant water risks. In China, coastal areas are among the most exposed globally to sea-level change and other maritime risks; inland, there are significant areas of water stress and water-quality damage.



Physical risk – agriculture

Southern Asia, in particular India, is very exposed to agriculture risk. In India, this is particularly via the large, informal rural economy (itself exposed to temperature and water scarcity risk²⁵).

Although Colombia has an average level of risk exposure to both physical atmospheric and water risk in those categories, when combined with its sizeable agricultural economy, these become a more significant risk factor. Poor management of fish stocks and soil quality worsen the outlook, and require major investor engagement.

Also broadly exposed to this risk are the soft commodities sectors of Peru and the Caribbean.



Transition risks

Transition risk scores are dominated by hydrocarbons producers, in particular countries that produce a lot of coal.

In general, few emerging markets are making adequate investment to support new activities that are less vulnerable to climate and nature risks.



Financial and socio-economic resilience

There is a strong correlation between countries with weak indicators in terms of fiscal and financial resilience, and those with weaker scores for physical resilience.

In Latin America, the combination of older populations and weak infrastructure drag Argentina towards weaker scores. Gulf Cooperation Council countries with significant corporate debt stocks and unfavourable demographics also score less well.

25. Hidden risks and untapped opportunities: water and the Indian banking sector. WWF, 2019. https://wwfeu.awsassets.panda.org/downloads/hidden_risks_and_untapped_opportunities_water_and_the_indian_banking_sector_1_.pdf

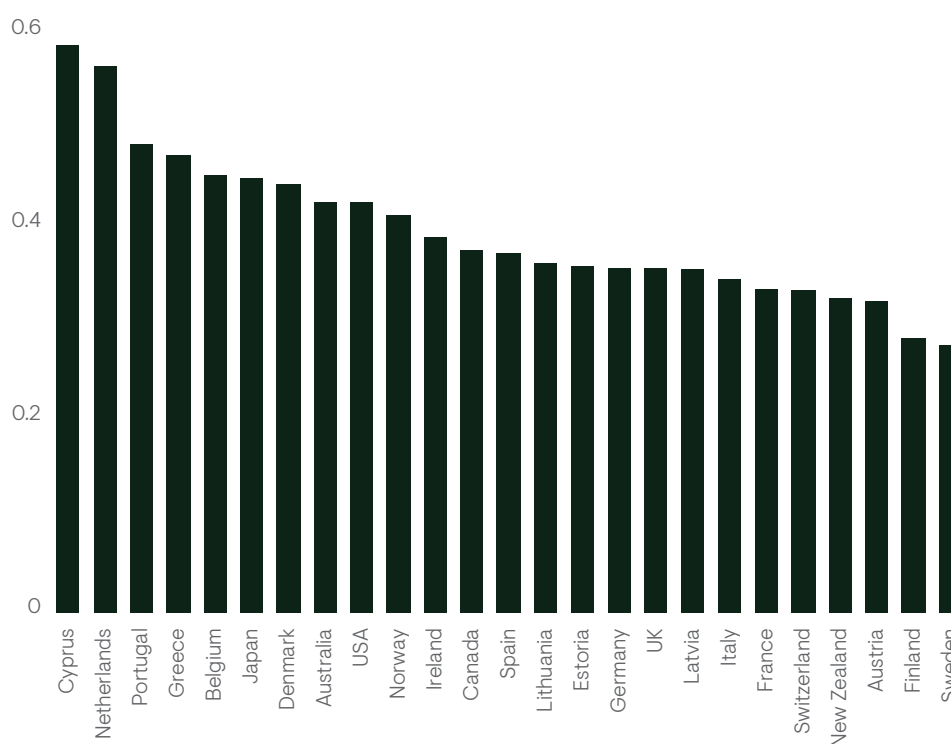
26. Ibid.

Developed markets

We focus here on developed markets as classified by the IMF/World Bank, but exclude those classified as emerging markets for fixed income investment purposes (e.g. Singapore). We include developed markets which are investment grade and high yield, also including the Baltic states. Our main findings are:

- The Netherlands is one of the highest risk developed markets on total risk score, alongside the smaller and economically less resilient Mediterranean countries.
- The geographical location of Cyprus means that it faces the most severe physical risks outside of Gulf Cooperation Council countries, and with an economy that has a larger proportion of existing economic activity not adapted to those risks.

Developed markets: overall risk (highest to lowest risk)



Source: Ninety One, June 2020. While the CNSI works on a scale of 0-1 with zero being highest risk and 1 being lowest, for visual representation scores were subtracted from 1 for the above chart.

Sub-component index results – developed markets



Biodiversity and natural capital

In Europe, Portugal stands out as having more negative trends in deforestation and land use, as well as greater long-term vulnerability to economic loss from coastal biome erosion.

Australia is exposed across a wide range of indicators, with falling land productivity projected to continue up to 2050.



Physical risk – atmospheric

The greatest risk exposure is in the Mediterranean, with Greece and Cyprus particularly exposed to the impacts of temperature through several channels, especially drought.

Italy faces similar risks, albeit somewhat more moderately, but with additional exposure to risk from storms and flooding.



Physical risk – water

Water risk is high in many Southern European countries, given the anticipated stress on domestic water assets together with higher temperatures.

A number of developed countries face particularly high exposure to water risk from flooding and sea-level changes, the UK being a prominent example.

Netherlands scores very poorly in terms of sea level and coastal risk.



Physical risk – agriculture

In Southern European countries with material agricultural sectors (Cyprus and Greece), agriculture risk interacts with other forms of physical risk.

New Zealand shows some exposure: despite the lower projected impact of climate change, the importance of agriculture to New Zealand's economy raises the risk score.



Transition risks

Australia, with its commodity-intensive economy is one of the most exposed countries in aggregate to the transition risk indicators.

Other economies with material hydrocarbons exposure flag risks too, but at less than the magnitude of Australia.



Financial and socio-economic resilience

In general, the resilience risk score for most of developed markets is lower relative to those of emerging markets, even for high-yield markets such as Greece given the umbrella provided by the EU financially and in terms of resilient infrastructure and services. Japan scores less well given long-term fiscal vulnerabilities which may reduce the country's capacity to respond to environmental risk over the longer term.

Opportunities and implications for green and SDG bond issuance

The CNSI should not be seen only, or principally, as a measure of risk, but also as a way of highlighting opportunities to allocate capital to environmental investments that offer the greatest potential.

Based on the CNSI metrics, we note a number of potential opportunities and urgent issues that need to be addressed in climate and SDG bond markets:

- **Chile** has been an active early emerging market issuer in green bond markets. Given the physical risks (e.g. drought, pollution) in the country, such instruments could offer investors the chance to contribute to Chile's future sustainable growth.
- A number of other larger emerging markets have been discussing, and laying the groundwork for, green and SDG bond issues. We believe the CNSI offers guidance on the areas that governments should prioritise in growing these markets:
- For **India** and **China**, which have made strong progress in renewable energy, there is further upside from additional financing in these areas (with China also set to improve its green bond taxonomy)²⁷. Bond issuance focused on water infrastructure (e.g., also including nature-based solutions such as protection and restoration of water-shed forests for water regulation and supply) appears an equally high priority in terms of allowing investors to provide capital to high-marginal-growth investments.
- In Latin America, **Brazil**, **Colombia** and **Peru** are developing plans to issue green and SDG bonds. Issuance to address biodiversity and climate would appear to be of very high marginal value for those countries, addressing the physical risk to their agricultural sectors.
- In **Indonesia** and **Malaysia**, planned green bond issuance should be complemented by issuance to address risks to natural capital and agriculture. Such bonds could also tie into SDGs related to inclusive growth and sustainable infrastructure. For example, in Malaysia deforestation measures remain a challenge, and issuance could be tied more directly to improvements in policy and implementation. In Indonesia, land coverage of protected areas is relatively low, and could form a more concrete pillar of SDG bond issuance, together with tying such bonds to inclusive growth and sustainable infrastructure.
- Issuance in **Gulf Cooperation Council** countries and former **Commonwealth of Independent States** (CIS) countries appear to be best focused on addressing transition risks over the medium term related to hydrocarbons, together with atmospheric physical risk from heat waves. **Colombia** also looks like a strong candidate for such issuance.

27. For further details: <https://www.reuters.com/article/us-china-environment-finance/china-excludes-clean-coal-projects-from-list-eligible-for-green-bonds-idUSKBN2350FW>

Conclusion and next steps

It is abundantly clear that climate change and the loss of nature pose an unprecedented existential threat to humanity. These highly complex and incredibly urgent environmental challenges can only be solved through a sustained and systemic transformation among all stakeholders – including individuals, households, communities, firms and governments. As lenders, investors and insurers to all these stakeholders, financial institutions will be crucial in enabling this transformation at the required speed and scale.

The Climate and Nature Sovereign Index (CNSI) is a first step towards harnessing the potential of the sovereign debt asset class – one of the biggest segments of the global financial system – in helping the global economy transition to a more sustainable and resilient development pathway. It sheds new light on climate- and nature -risk exposures at the country level, in both developed and emerging markets. It is unique in that it combines the financial and economic indicators that currently inform the risk modelling of the sovereign debt asset class with real-time, forward-looking indicators to present a comprehensive assessment of a country's environmental risk exposure. Such an assessment will enable strong, evidence-based action by different stakeholders, particularly sovereign debt investors and governments, towards ensuring a resilient economy and overall sustainability.

While the CNSI is just one of many possible ways to improve the understanding of environmental risks at a country level, the continued enhancements to the framework – through widespread adoption, combined with the fast-paced improvements in remote-sensing data – could go a long way in harnessing the power of financial markets to save our natural world.

The new field of spatial finance, which harnesses the rapid evolution of satellite technology, computing power and machine learning, has a key role to play in this journey. It is accelerating the ability of investors to use more 'real-time' indicators for, e.g. monitoring of habitats and protected areas. It is also facilitating forward-looking forecasts and projections based on models that can be updated annually. It is thanks to developments in this field that we have been able to create the CNSI.

A comprehensive assessment of a country's environmental risk exposure will enable strong, evidence-based action by different stakeholders

The CNSI is not only a measure of risk; it should also help identify the opportunities to allocate capital to where it is most needed and to help investors engage effectively with sovereigns, with the aim of improving environmental and economic sustainability and resilience. To achieve this, it must be complemented with new financing mechanisms. That includes new types of bonds that incentivise investment patterns that help to build this resilience and help steer capital towards areas where investment in natural assets could deliver the biggest economic and social benefits. Working in partnership with official multi-lateral and development financing institutions will be key to creating some of these new funding instruments.

Further research is needed on the integration of environmental risk within the sovereign debt asset class and on the transmission pathways between environmental and financial risks. We suggest that the framework to construct the CNSI can provide the basis for this. We encourage different stakeholders to, use, improve and refine it. Business intelligence providers are particularly well placed to capture and analyse the data and update the index on an ongoing basis.

Further information on the index is available from the authors on request. We hope this initiative will mark an important step in helping various stakeholders – including investors, sovereigns and international financial institutions – to contribute to the ultimate objective of protecting the natural world, building a more sustainable and resilient global economy, and avoiding the severe economic and human consequences of failing to do so.

The CNSI should also help identify the opportunities to allocate capital to where it is most needed

Appendix 1

How the CNSI can complement, and challenge, ESG scores

ESG research at Ninety One has the same status as research into traditional drivers of asset returns. Investment professionals are responsible for sustainability-related analysis and scoring, and are supported by centralised ESG data and expertise. Regular meetings are held to discuss and update ESG scorecards. Crucially, our process focuses on forward-looking rates of change, especially in policy but also in medium-term risks.

The CNSI provides a valuable and fascinating perspective on our ESG research. We observe a high correlation between the CNSI results and our positive ESG scores for countries like Chile, Singapore and Costa Rica. Similarly, in countries like India and Indonesia, the CNSI reinforces the challenging dynamics identified in our ESG assessments of environmental policy.

On the other hand, the CNSI challenges our positive scores for countries such as Thailand and Peru, as well as frontier markets such as Vietnam. Peru has made significant strides in certain areas of ESG policy such as mining transparency and trying to address social conflicts connected to mining and water assets. But the degree of exposure to atmospheric temperature change in the future suggests its initial efforts need to be accelerated in areas of adaptation. Thailand is likewise highly exposed to future temperature increases, but also to sea level rises, flooding risk and the combined potential impact of these trends on its agricultural system.

While our overall ESG scores are based on a view on the forward-looking change and delivery of policy, mitigating environmental risks and achieving climate goals is clearly going to be harder in countries with more challenging initial conditions. The complementary perspectives offered by the CNSI and our ESG research, combined with our ongoing engagement with officials in these countries, will enable us to refine our views going forward.

Appendix 2

Climate & Nature Sovereign Index: Indicators



Biodiversity and natural capital

Indicator	Source
Deforestation trends over last decade	Hansen/UMD/Google/USGS/NASAGFW [On-line], [04/2020], https://glad.geog.umd.edu/
GLAD weekly deforestation where available	Hansen/UMD/Google/USGS/NASAGFW [On-line], [04/2020], https://glad.geog.umd.edu/
Land cover change	Joint Research Centre of the European Commission (year), The Digital Observatory for Protected Areas (DOPA) Explorer 4 [On-line], [06/2020], Ispra, Italy. http://dopa-explorer.jrc.ec.europa.eu
Land cover change within Protected Areas	Joint Research Centre of the European Commission (year), The Digital Observatory for Protected Areas (DOPA) Explorer 4 [On-line], [06/2020], Ispra, Italy. http://dopa-explorer.jrc.ec.europa.eu
Land cover fragmentation	Joint Research Centre of the European Commission (year), The Digital Observatory for Protected Areas (DOPA) Explorer 4 [On-line], [06/2020], Ispra, Italy. http://dopa-explorer.jrc.ec.europa.eu
Land cover fragmentation within Protected Areas	Joint Research Centre of the European Commission (year), The Digital Observatory for Protected Areas (DOPA) Explorer 4 [On-line], [06/2020], Ispra, Italy. http://dopa-explorer.jrc.ec.europa.eu
Land productivity	Joint Research Centre of the European Commission (year), The Digital Observatory for Protected Areas (DOPA) Explorer 4 [On-line], [06/2020], Ispra, Italy. http://dopa-explorer.jrc.ec.europa.eu
Land productivity within Protected Areas	Joint Research Centre of the European Commission (year), The Digital Observatory for Protected Areas (DOPA) Explorer 4 [On-line], [06/2020], Ispra, Italy. http://dopa-explorer.jrc.ec.europa.eu
Impact on GDP by 2050 due to change in pollination services	WWF, Purdue University and University of Minnesota, [06/2020], https://www.wwf.org.uk/globalfutures
Impact on GDP by 2050 due to change in coastal protection services	WWF, Purdue University and University of Minnesota, [06/2020], https://www.wwf.org.uk/globalfutures
Impact on GDP by 2050 due to change in water yield	WWF, Purdue University and University of Minnesota, [06/2020], https://www.wwf.org.uk/globalfutures
Impact on GDP by 2050 due to change in timber production	WWF, Purdue University and University of Minnesota, [06/2020], https://www.wwf.org.uk/globalfutures
Impact on GDP by 2050 due to change in fish production	WWF, Purdue University and University of Minnesota, [06/2020], https://www.wwf.org.uk/globalfutures

Indicator	Source
Impact on GDP by 2050 due to change in carbon sequestration	WWF, Purdue University and University of Minnesota, [06/2020], https://www.wwf.org.uk/globalfutures
Mineral rents (% GDP)	World Development Indicators, [On-line], [06/2020], https://databank.worldbank.org/source/world-development-indicators
Mining exports (% goods exports)	World Development Indicators, [On-line], [06/2020], https://databank.worldbank.org/source/world-development-indicators
% Terrestrial Protected Areas	IUCN and UNEP-WCMC (2020), The World Database on Protected Areas (WDPA) [On-line], Cambridge, UK: UNEP-WCMC. www.protectedplanet.net
Ocean biodiversity	Ocean Health Index, [On-line], [06/2020] http://www.oceanhealthindex.org



Physical risk – atmospheric

Indicator	Source
Natural Hazard Risk (0-10) (10 = highest risk)	INFORM https://drmkc.jrc.ec.europa.eu/inform-index
Projected economic loss from temperature change	Burke, M., Davis, W.M. and Diffenbaugh, N.S. 2018, Large potential reduction in economic damages under UN mitigation targets. Nature 557, 549–553. https://doi.org/10.1038/s41586-018-0071-9
Days of extreme heat	World Bank Open Data, [On-line], [06/2020], https://data.worldbank.org/
Heatwave risk probability	World Bank Open Data, [On-line], [06/2020], https://data.worldbank.org/
% land exposed to drought by 2050	Isipedia (In press), [On-line], [04/2020], https://www.isipedia.org/
% population exposed to drought by 2050	Isipedia (In press), [On-line], [04/2020], https://www.isipedia.org/
Drought probability	World Bank Open Data, [On-line], [06/2020], https://data.worldbank.org/
Ocean carbon storage	http://www.oceanhealthindex.org/
Atmospheric particulates exposure	OECD https://www1.compareyourcountry.org/green-growth-indicators/en/1/all/default
Atmospheric total pollution exposure	OECD https://www1.compareyourcountry.org/green-growth-indicators/en/1/all/default



Physical risk – water

Indicator	Source
Population impacted by riverine flood risk (0-5) (5=highest risk)	World Resources Institute, sourced from Haver Analytics.
Population close to sea level	World Development Indicators, [On-line], [06/2020], https://databank.worldbank.org/source/world-development-indicators
Projected sea level rise risk	Coastal DEM
Freshwater withdrawal rates	Food and Agriculture Organization of the United Nations (FAO), 2020. Aquastat Main Database, [On-line], [06/2020], http://www.fao.org/nr/water/aquastat/data/query/index.html

Indicator	Source
Water productivity	Food and Agriculture Organization of the United Nations (FAO), 2020. Aquastat Main Database, [On-line], [06/2020], http://www.fao.org/nr/water/aquastat/data/query/index.html
WRF - Scarcity & drought risk	WWF Water Risk Filter, [05/2020] https://waterriskfilter.panda.org/en/About/DataAndMethods
WRF - Flood risk	WWF Water Risk Filter, [05/2020] https://waterriskfilter.panda.org/en/About/DataAndMethods
WRF - Water quality and impairment risk	WWF Water Risk Filter, [05/2020] https://waterriskfilter.panda.org/en/About/DataAndMethods
WRF - Ecosystem service loss risk	WWF Water Risk Filter, [05/2020] https://waterriskfilter.panda.org/en/About/DataAndMethods
Improved sanitation	World Development Indicators, [On-line], [06/2020], https://databank.worldbank.org/source/world-development-indicators
Extreme rainfall risk	World Bank Open Data, [On-line], [06/2020], https://data.worldbank.org/
Clean Ocean waters	Ocean Health Index, [On-line], [06/2020] http://www.oceanhealthindex.org
Coastal protection	Ocean Health Index, [On-line], [06/2020] http://www.oceanhealthindex.org



Physical risk – agriculture

Indicator	Source
Agriculture, Forestry & Fishing, Value Added (% GDP)	World Development Indicators, [On-line], [06/2020], https://databank.worldbank.org/source/world-development-indicators
Agricultural Exports (% Goods Exports)	World Development Indicators, [On-line], [06/2020], https://databank.worldbank.org/source/world-development-indicators
Employment in Agriculture (% Total)	World Development Indicators, [On-line], [06/2020], https://databank.worldbank.org/source/world-development-indicators
Rural Population (% Total)	World Development Indicators, [On-line], [06/2020], https://databank.worldbank.org/source/world-development-indicators
Projected change in agricultural output RCP 2.6 vs 8.5	Ostberg, S., Schewe, J., Childers K., and Frieler, K., 2018. Changes in crop yield and their variability at different levels of global warming. Earth Syst. Dynam., 9, 479–496, https://doi.org/10.5194/esd-9-479-2018
Population growth % (2050 vs 2020)	HNPStats
Sustainable Nitrogen Management (100 = target)	Environmental Performance Index, [On-line], [06/2020], https://epi.yale.edu/epi-indicator-report/SNM
Prevalence of undernourishment (% population)	World Development Indicators, [On-line], [06/2020], https://databank.worldbank.org/source/world-development-indicators
Global food security index	Global Food Security Index, [On-line], [06/2020], https://foodsecurityindex.eiu.com/
Marine food security	Ocean Health Index, [On-line], [06/2020], http://www.oceanhealthindex.org
Growing season length	World Bank Open Data, [On-line], [06/2020], https://data.worldbank.org/



Transition risk

Indicator	Source
Oil rents (% GDP)	World Development Indicators, [On-line], [06/2020], https://databank.worldbank.org/source/world-development-indicators
Natural Gas rents (% GDP)	World Development Indicators, [On-line], [06/2020], https://databank.worldbank.org/source/world-development-indicators
Fuel Exports (% Goods Exports)	World Development Indicators, [On-line], [06/2020], https://databank.worldbank.org/source/world-development-indicators
Environmental taxes as % GDP	OECD https://www1.compareyourcountry.org/environmental-taxes/en/3/all/default
Environmental taxes as % revenue	OECD https://www1.compareyourcountry.org/environmental-taxes/en/3/all/default
Coal Rents (% GDP)	World Bank Open Data, [On-line], [06/2020], https://data.worldbank.org/
Net Energy Imports (% Energy Use)	World Development Indicators, [On-line], [06/2020], https://databank.worldbank.org/source/world-development-indicators
Carbon intensity (CO2 Emissions per \$1k of GDP)	EDGAR, PRIMAP, source from Haver Analytics
Carbon intensity (GHG Emissions per \$1k of GDP)	EDGAR, PRIMAP, source from Haver Analytics
Demand generated CO2 per capita	https://www1.compareyourcountry.org/green-growth-indicators/en/1/all/default
Supply side CO2 productivity	https://www1.compareyourcountry.org/green-growth-indicators/en/1/all/default
Ex-Hydro Renewables Production (% total electricity production)	International Renewable Energy Agency, [On-line], [06/2020], https://www.irena.org/Statistics
Hydro Production (% total electricity production)	World Development Indicators, [On-line], [06/2020], https://databank.worldbank.org/source/world-development-indicators
Production from Hydrocarbons (% total electricity production)	World Bank Open Data, [On-line], [06/2020], https://data.worldbank.org/
Potential for renewable investment	BNEF
Green complexity potential	Mealy, P. & Teytelboym, A. (2019). 'Economic Complexity and the Green Economy'. INET Oxford Working Paper No. 2018-03 https://www1.compareyourcountry.org/green-growth-indicators/en/3/all/default
Environmental patents	https://www1.compareyourcountry.org/green-growth-indicators/en/3/all/default
Coastal economic health	Ocean Health Index, [On-line], [06/2020] http://www.oceanhealthindex.org
Coastal tourism and recreation	Ocean Health Index, [On-line], [06/2020] http://www.oceanhealthindex.org



Financial and socio-economic resilience

Indicator	Source
Debt/GDP	Moody's
Headline deficit/GDP	IMF WEO, accessed via Haver Analytics
External debt/reserves	Moody's
Interest/revenue	Moody's
External interest/exports	Moody's
Subsidies & other transfers % expenses	World Bank World Development Indicators, sourced from Haver Analytics
Urban population living in slums (% Total)	World Bank World Development Indicators, sourced from Haver Analytics
Urban population in 2050 (% Total)	World Development Indicators, [On-line], [06/2020], https://databank.worldbank.org/source/world-development-indicators
Aid Dependency (0-10) (10 = highest risk)	INFORM https://drmkc.jrc.ec.europa.eu/inform-index
External Health Expenditure (% Total)	World Development Indicators, [On-line], [06/2020], https://databank.worldbank.org/source/world-development-indicators
Age Dependency Ratio (% Working age population)	World Development Indicators, [On-line], [06/2020], https://databank.worldbank.org/source/world-development-indicators
Physical Infrastructure (0-10) (10 = highest risk)	INFORM https://drmkc.jrc.ec.europa.eu/inform-index
WRF - sector-weighted operational risk	WWF Water Risk Filter, [05/2020] https://waterriskfilter.panda.org/en/About/DataAndMethods
Disaster Risk Reduction (0-10) (10 = highest risk)	INFORM https://drmkc.jrc.ec.europa.eu/inform-index

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