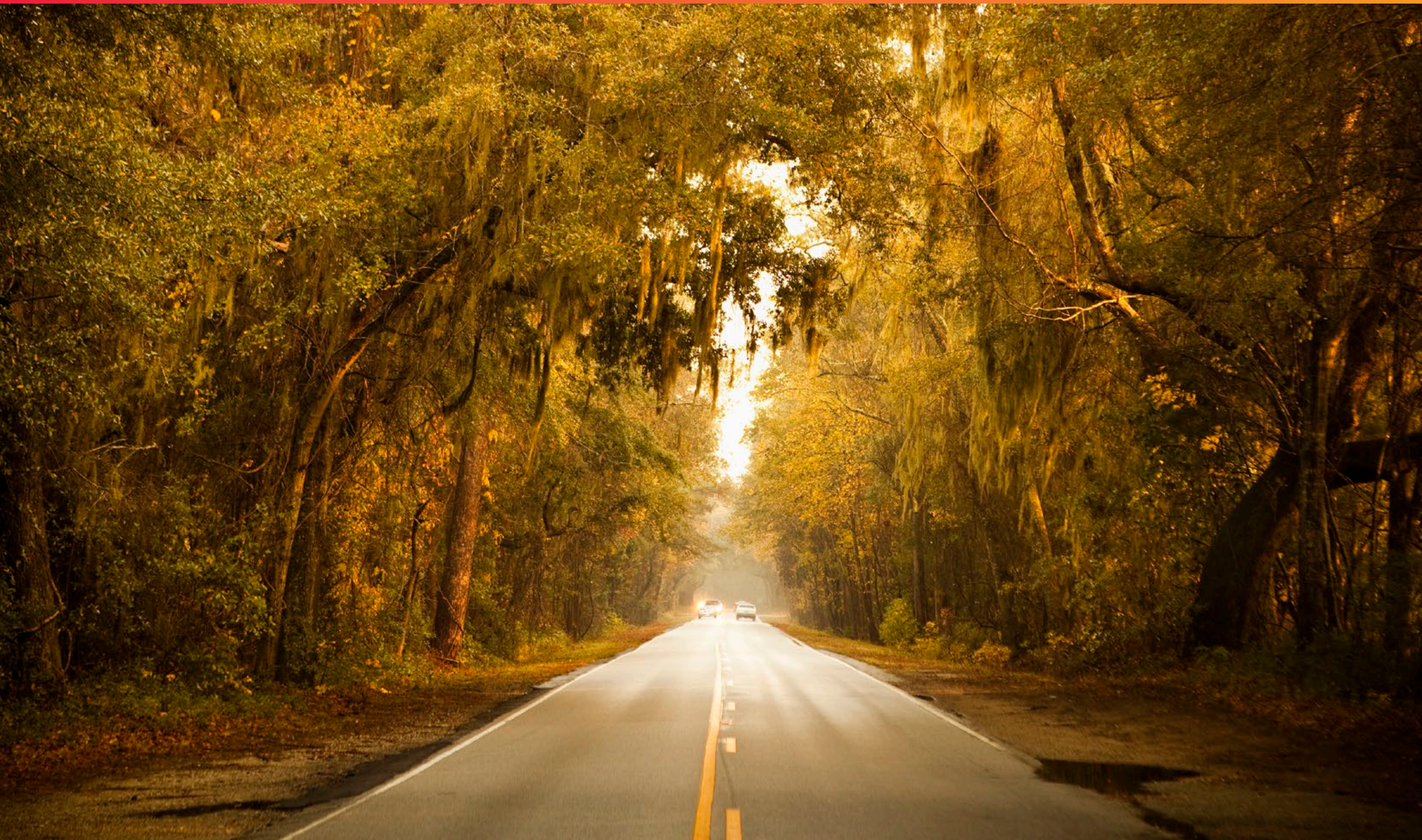
Swiss Re
Institute

Biodiversity and Ecosystem Services

A business case for re/insurance



FOREWORD

Dear Reader,

In the last few years the world has made great progress in understanding the impact of climate change. Less understood – but just as important – is the impact of biodiversity risks on the economy.

Biodiversity and Ecosystem Services (BES) underpin all economic activity in our societies globally and should be part of strategy discussions across financial services. Already today, 55% of global GDP is moderately or highly dependent on BES, according to our own research. The impact on financial assets is also enormous: The Dutch National Bank estimates a staggering EUR 510 billion or 36% of all investments from Dutch financial institutions would be lost if the ecosystem services underpinning the Dutch economy were no longer available.

The implications of BES decline have been a topic for us for many years. In recent times, we have noticed an increasing interest among our clients in the topic as all stakeholders start to understand how BES affect asset values and the economy in general. This has implications on the re/insurance industry, but also offers opportunities.

Assessing biodiversity risks is complex as there is a massive underlying collection of risks. To help assess the risks and foster dialogue around biodiversity we have designed a Biodiversity and Ecosystem Services (BES) Index. It shows that in 20% of all countries, ecosystems are in a fragile state for more than 30% of the entire country area. The index facilitates the process of incorporating re/insurance relevant BES factors into business decision-making and provides BES-related benchmarks.

By using this global BES-relevant information, companies and other stakeholders have a new tool to manage the operational, transitional, and reputational risks connected to BES decline.

At the same time, the index findings can be used to develop strategies and products to protect businesses, societies and the environment.

If you are interested in discussing business solutions built on the BES Index that contribute to keeping Biodiversity and Ecosystem Services healthy and thriving, we look forward to hearing from you.

Christian Mumenthaler
Group Chief Executive Officer
Swiss Re Ltd.

1

Biodiversity and Ecosystem Services (BES) – a business case for the re/insurance industry

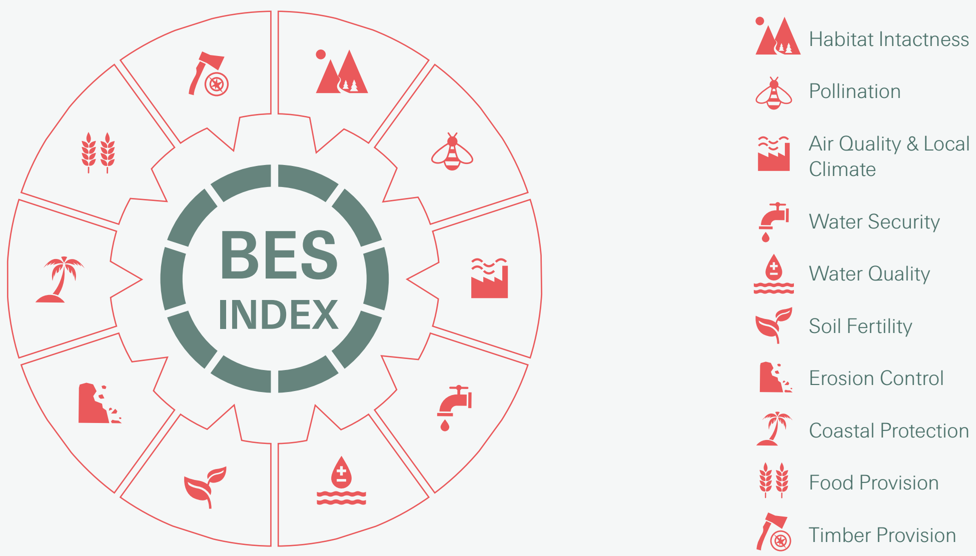
The destruction of the Aral Sea

The near destruction of the Aral Sea is a sharp reminder of the deep impact an ecosystem collapse can have on people and economies. During the Soviet era, the Aral Sea was a thriving economy: thousands of people lived in the region, making a living from the surrounding natural resources. The fishing industry supplied the country with nearly two out of every ten fish while the water feeding the lake supported agriculture. When this water was diverted to irrigate fields in other regions, inflows to the lake declined and it started to disappear.[1]

Today the sea as it was – despite some successful restoration efforts – is all but gone. Much of the lake sediments contain high concentrations of pesticides accumulated over decades from land-based run-off. The extent of this man-made impact is staggering: the local economy and agriculture systems – and with them the biodiversity found in and around the lake and islands – collapsed. As a result, the vast majority of the population had to move away because the foundation of their economies and livelihoods had disappeared.

The Aral Sea shows what can happen when a key ecosystem collapses. But which ecosystem services are most relevant for the re/insurance industry – for risk assessment, underwriting and investment allocation? Figure 1 shows those services we identified as most relevant to re/insurance.

Figure 1: Ecosystem services identified based on re/insurance business relevance and data availability.



Source: Swiss Re Institute

[1] See the documentation at http://www.columbia.edu/~tmt2120/introduction.htm

How BES decline can relate to the re/insurance industry

The re/insurance industry relies on functioning economies in which citizens and society can generate valuable assets and activities that are worth protecting. But what if insurable assets are lost or abandoned due to ecosystem collapse like with the Aral Sea? Could such a collapse affect other economically important regions? The analysis from the Dutch National Bank (DNB)[2] in conjunction with the IPBES (2019)[3] suggests it could. DNB (2020) assesses the risks stemming from biodiversity loss and ecosystem services decline on investments held by Dutch financial institutions. A loss of ecosystem services "would lead to substantial disruption of business processes and financial losses" according to the study (2020:16). The study analysed indirect dependencies on ecosystem services and concluded that EUR 510 billion, or 36% of the EUR 1.4 trillion in investments held by Dutch financial institutions, is highly or very highly dependent on one or more ecosystem services. This represents the total expected financial losses if ecosystem services were at zero. Other recent biodiversity related studies from financial market actors or policymakers further back this up.[4]

But how exactly – and where? First let's look at the how. Natural assets – such as water, soil, and biodiversity – provide important ecosystem services to humans. These include sources of nature-based materials, such as timber fibers. They provide inputs into new medicine, pollination services, erosion control or clean air. The last two are good examples of services particularly relevant for the re/insurance industry.

Let's consider erosion control on the property side of the business covering storm surges, floods and landslides. Coastal and river-bordering forests and mangroves provide key erosion protection. Roots build a natural bulwark against waves and can also store water in case of heavy rainfalls. In areas where forests have disappeared, landslides are more frequent and storm surges can move further inland, causing property losses covered by re/insurance.

On the Life & Health side, respiratory diseases are one of the key drivers of claims globally, with costs continuing to rise. Respiratory diseases are spatially strongly connected to the absence of forests. Forests can naturally purify air and where they exist, the burden of respiratory diseases is lower than in areas without trees.[5,6]

These are just two examples of how the re/insurance industry can be affected. We could list more examples: business interruption in shipping and power interruption during drought, adverse consequences for agriculture due to water scarcity and/or soil degradation.

While these examples are presented as risks to businesses, they may also be turned into opportunities for re/insurers and investors. Conservation investments into ecosystems may strengthen their services and reduce these risks.

2 Dutch National Bank DNB and PBL Netherlands Environmental Assessment Agency (DNB 2020). Indebted to nature. Exploring biodiversity risks for the Dutch financial sector. Authored by van Toor, J., Piljic, D., Schellekens, G., van Oorschot, M., Kok, M., June 2020.

3 IPBES 2019. Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). E. S. Brondizio, J. Settele, S. Díaz, and H. T. Ngo (editors). IPBES secretariat, Bonn, Germany. https://ipbes.net/global-assessment.

4 OECD 2019. Biodiversity: Finance and the Economic and Business Case for Action. Report prepared for the G7 Environment Ministers' Meeting 5–6 May 2019. Paris. The OECD (2019) highlights that a third of the negative biodiversity impacts in Central and South America, and a quarter of the negative biodiversity impacts in Africa are driven by consumption elsewhere.
TEEB 2012. The Economics of Ecosystems and Biodiversity in Business and Enterprise. Edited by Joshua Bishop. Earthscan, London and New York.
The 2020 WEF Global Risks Report includes biodiversity loss among the top risks (WEF 2020). World Economic Forum WEF 2020. The Global Risks Report. Geneva/Cologny 2020.
WWF France and Axa 2019. Into the wild. Integrating nature into investment strategies. Paris 2019.
PwC and WWF Switzerland 2020. Nature is too big to fail. Biodiversity: the next frontier in financial risk management. Zürich January 2020.

5 Meenakshi R., George, L.A., Rosenstiel, T.N., Shandas, V., Dinno, A. (2014). Assessing the relationship among urban trees, nitrogen dioxide, and respiratory health. Environmental Pollution, Volume 194, November 2014, Pages 96-104, ISSN 0269-7491, dx.doi.org/10.1016/j.envpol.2014.07.011

6 Nowak, D., Hirabayashi, S., Bodine, A., Greenfield, E. (2014). Tree and forest effects on air quality and human health in the United States. Environmental Pollution 193 (2014) 119-129. https://www.fs.fed.us/nrs/pubs/jrnl/2014/nrs_2014_nowak_001.pdf

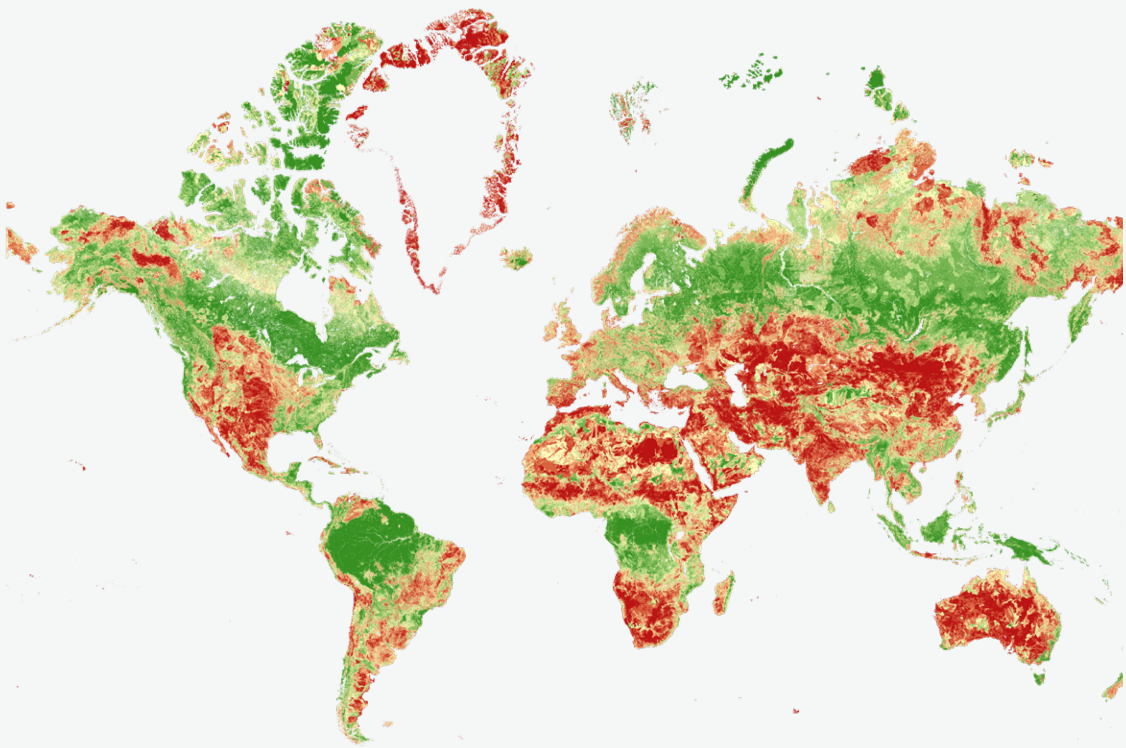
Since all economic sectors depend on BES in some way, let's focus on the question of where we are today: How does BES decline relate to the re/insurance industry, and can it be measured?

BES status: Introducing the Swiss Re Institute BES Index

To understand if BES are on the decline, we need to know which ecosystem services are relevant in a given location and measure their health status. Swiss Re Institute (SRI) has developed the BES Index to support such analysis.[7] The ten ecosystem services introduced in Figure 1 have been aggregated to the overall SRI BES Index shown in Figure 2. This map provides a visualization of the state of the different ecosystem services captured by the SRI BES Index for every square kilometer of land.

The map for the overall index (Figure 2) shows many "red" areas (ie, "Very Low" SRI BES Index value), indicating where BES are comparatively fragile and any further use could accelerate a decline. Some of these fragile areas include densely populated and economically important regions in which the re/insurance industry protects many assets and activities. Slow but steady degradation may lead to tipping points, and a subsequent abrupt ecosystem collapse. You will find definitions, methodology and references in full detail in Chapter 3.

Figure 2: Global SRI BES Index map at 1 km² resolution



Biodiversity & Ecosystem Services (BES) Index

- Very Low (<15)
- Low (15–30)
- Moderate (30–45)
- Moderate (45–60)
- Moderate (60–75)
- High (75–90)
- Very High (>90)

Source: Swiss Re Institute and multiple data sources (see appendix for all details)

[7] BES Index Patent registration is pending.

As we now know, the state of BES in several key regions is already 'low' compared to other regions. What does this mean, and how can this be incorporated into a business strategy assessment?

There are key risk management considerations:

- Risk selection: Insure what is insurable.
- Risk management: Insureds are expected to take cost-effective risk management measures.
- Adequate risk pricing: Re/insurance premiums reflect the residual risk after risk management.
- Risk diversification: The re/insurance industry diversifies its business based on re/insurance lines of business, geography and time.

To implement these principles, re/insurance follows a data-based approach. Here we outline how this approach helps to make the right business decision. The following chapters present this approach in more detail.

To connect exposures due to BES decline with considerations relevant for re/insurance, the following information is required:

- What BES are present at the location?
- What is the status of the BES in the location?
- How dependent is the insurable risk on BES?
- What could the role of investors and re/insurance be in building nature-based solutions that improve ecosystem services and help reduce risks?

The SRI BES Index presented in this publication helps answer these key questions. Consider the following example: a large coastal property is located in a hurricane area. Elevation above sea level is only 10 m and the key peril is storm surge. The ecosystem service that will determine if the property is heavily exposed to storm surge is 'protection by coral reefs or mangrove forests' along the coast. If intactness is high, the risk is insurable for a lower premium. If it is low, the premium will be higher or the property may be uninsurable. If coral reefs or mangrove forests are destroyed, either man-made storm surge protection becomes necessary, or re/insurance will not be offered at all. In this example, we see a clear link between the health of a relevant BES and the cost and availability of re/insurance for a property whose value and insurability are dependent on the specific BES.

There are many examples linking specific BES to insurable assets and activities. By applying the SRI BES Index to relevant risks, re/insurance portfolios can be assessed for BES exposure. The SRI BES Index could also be relevant for corporate and government clients looking for re/insurance. It can be used to screen locations for factories, warehouses, and other properties.

The potential application of the SRI BES Index does not stop here. Insurers can also use it to assess their exposure on the investment side – for example, the index could be used to minimize investment exposure to BES degradation. This index also provides new opportunities for nature-based insurance solutions as well as investment possibilities.

In areas where ecosystem services are on the decline, the establishment of a funding mechanism through re/insurance and finance can protect them in the long term and represents a sustainable investment opportunity going forward. Box 1 provides further current examples of the economic impact and consequences of ecosystem degradation.

Box 1: Examples of the impact and consequences of ecosystem degradation

1 The loss of the Amazon forest impacts (micro)climate, water supply, carbon storage and soil integrity. Deforestation affects water supplies in Brazilian cities and neighboring countries. It also impacts the actual farms driving deforestation, causing water scarcity and soil degradation. Further deforestation may also impact water supply globally.[8]

2 Coral reef mining in Sri Lanka has resulted in severe coastal erosion and increased onshore destruction and loss of life from storms and tsunamis (eg the earthquake and tsunami event from 26 December 2004).[9]

3 Nutrient run-off (nitrogen and phosphorous) into rivers from agricultural practices in the US Mississippi watershed causes a dead zone in the Gulf of Mexico each year due to algal blooms and oxygen depletion, resulting in the collapse of shrimp and oyster fisheries (at least USD 300 million per year).[10]

[8] Welch, C. (2019) How Amazon forest loss may affect water – and climate – far away. National Geographic August 27 2019. https://www.fs.fed.us/nrs/pubs/jrnl/2014/nrs_2014_nowak_001.pdf

[9] Kumara T.P., Cumaranatunga, R., Linden, O. 2005. Bandaramulla Reef of Southern Sri-Lanka - Present status and impacts of coral mining. In: Linden, O., Souter, D., (eds.) Coral Reef Degradation in the Indian Ocean: Status report 2005. CORDIO/SAREC Marine Science, Sweden. 233 – 242.

[10] Microbial Life Educational Resources, https://serc.carleton.edu/microbelife/topics/deadzone/index.html

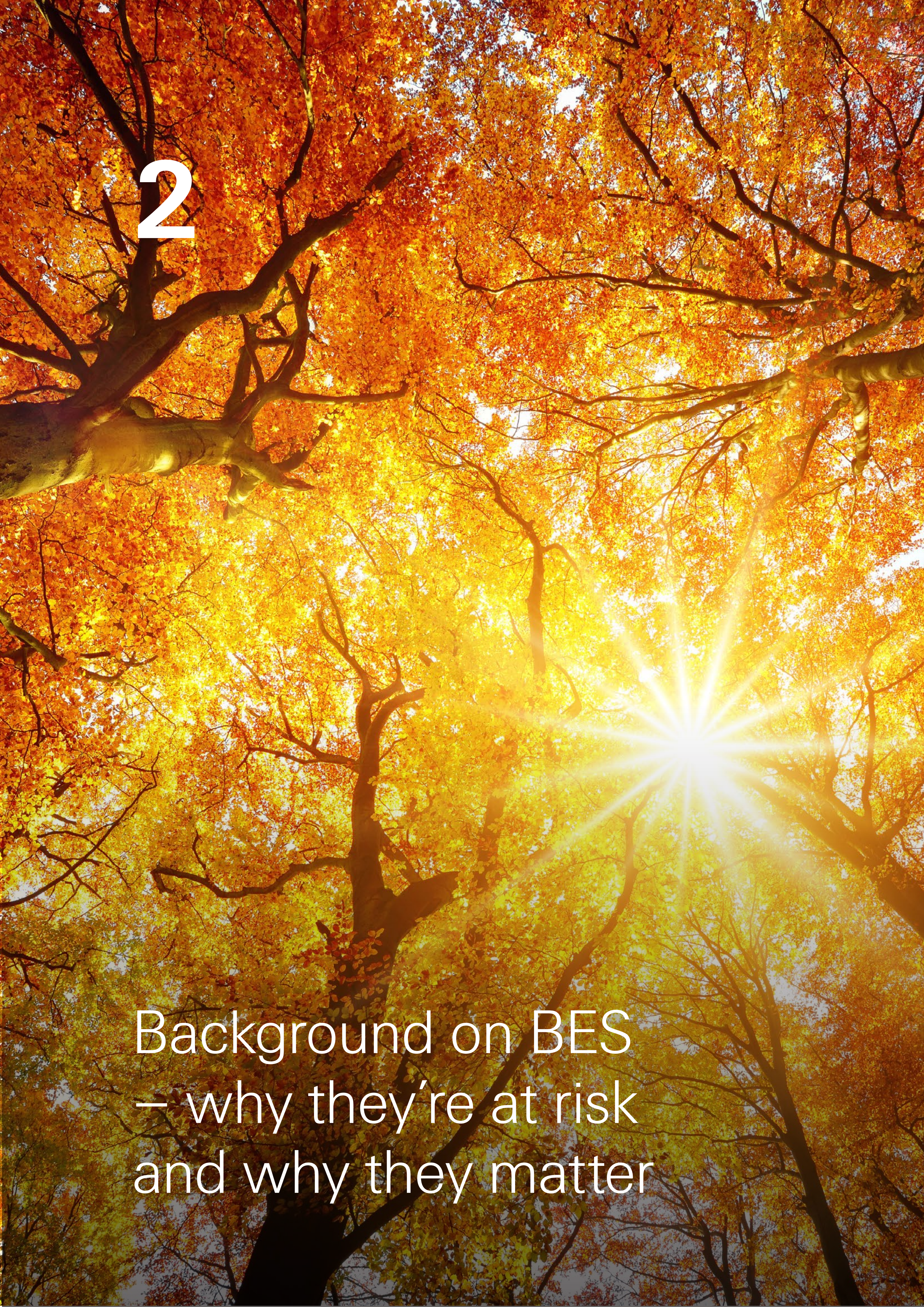
4 Invasive species may cost global agriculture USD 540 billion annually[11], or the US economy alone more than USD 100 billion per year.[12] The Eurasian watermilfoil, an example of an invasive aquatic plant species plant, has reduced the value of Vermont lakefront property by up to 16% and Wisconsin lakefront property by 13%.[13] Other examples are (i) invasive mussels that colonize and corrode water pipes and block the water flow, increasing operation costs for utilities; (ii) cheatgrass that fuels wildfires, increasing firefighting costs and damages to property; (iii) the Asian citrus psyllid that attacks orange groves.[14]

5 Biodiversity is critical to drug discovery with around half of all approved modern drugs being developed from wild species during the past 30 years. Recent critical examples: scientists developed the malaria drug artemisinin from sweet wormwood, while the Madagascan periwinkle and Pacific yew tree have both yielded treatments for cancer.[15]

6 Insects are the world's top pollinators and have declined by 40% in recent decades: 75% of critical food crops depend on animal pollination, including fruit, vegetables, nuts and seeds, as well as key crops like coffee and cocoa.[16] The global annual market value of animal pollinated crops is estimated between USD 235–577 billion (OECD 2019).

[11] Axa Research Fund 2019. Axa Research Guide Series. Biodiversity at Risk. Preserving the natural world for our future. Axa Paris, 2019.
[12] Pimentel D., Zuniga R., Morrison D. 2005. Update on the Environmental and Economic Costs Associated with Alien-Invasive Species in the United States. Ecological Economics 52. 273-288.
[13] U.S. Fish & Wildlife Service 2012. The cost of invasive species. online available at https://www.fws.gov/verobeach/PythonPDF/CostofInvasivesFactSheet.pdf
[14] Chin, J., Gao, G., Schloemann, R., Sharan S. 2018. Building resilience to the economic threat of invasive species. Swiss Re Institute 2018.
[15] Veeresham, C. 2012. Natural products derived from plants as a source of drugs. J Adv Pharm Technol Res. 2012 Oct-Dec; 3(4): 200–201. doi: 10.4103/2231-4040.104709.
[16] Swiss Re Institute 2018. Making a beeline for disaster? The decline of pollinators puts agriculture at risk. Authored by Schelske O., Xing L., Wong C., Trepp F., Swiss Re Institute 2018.

The next chapter gives more background on BES and their importance to economic activities. Afterwards, we describe how the SRI BES Index is composed and generated.



2

Background on BES – why they're at risk and why they matter

BES are vital for societies and economies to function. Figure 3 shows the interplay of biodiversity and ecosystem services with society and economy; Box 2 defines the relevant terms in greater detail.

Box 2: Definitions

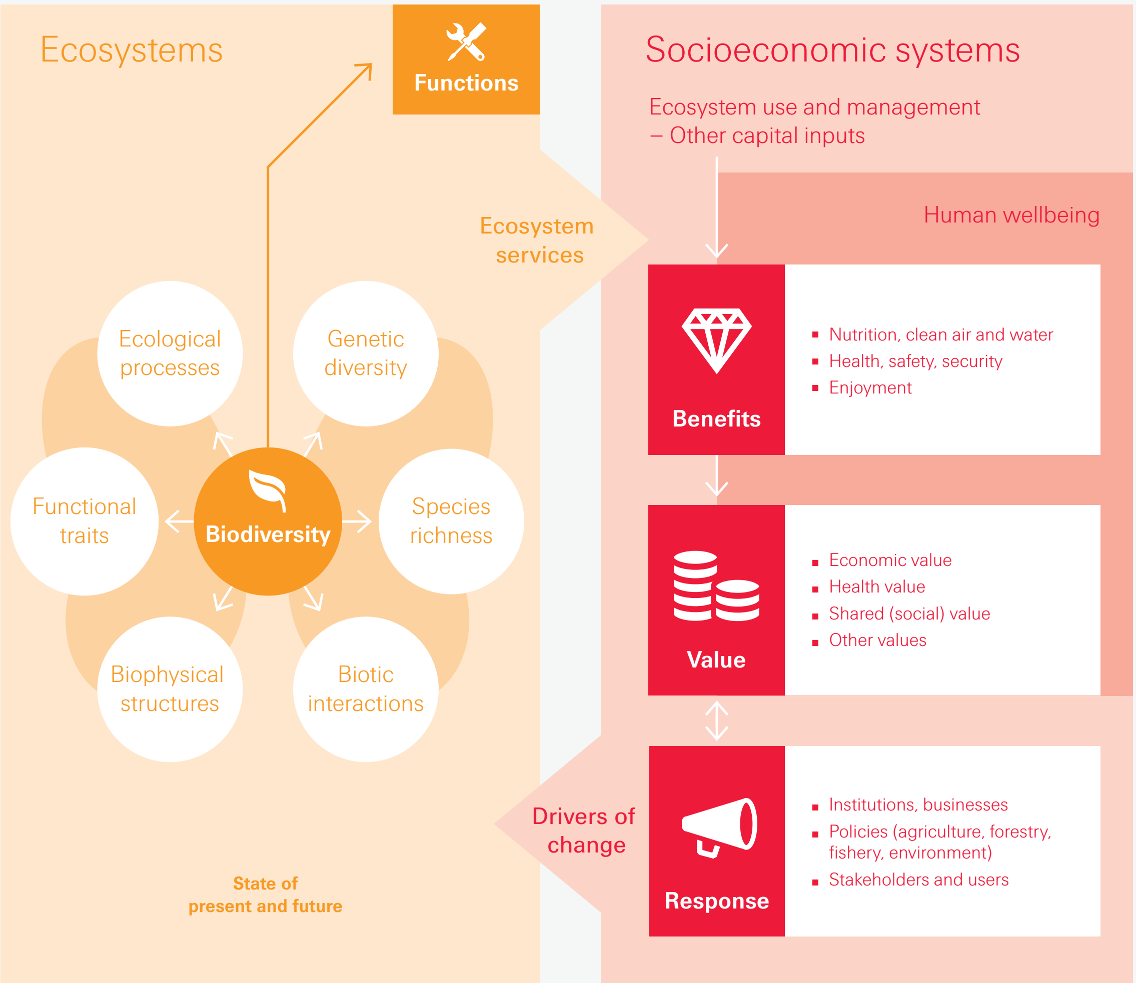
Biodiversity measures the number, variety, and variability of living organisms (animal and plant species, fungi, micro-organisms). It includes diversity within species, between species, and among ecosystems. The term also covers how diversity changes from one location to another and over time (UN 1992; Gaston/Spicer 2004).[17] Inventories of species remain incomplete – mainly due to limited field sampling – to provide an accurate picture of the extent and distribution of all components of biodiversity (Purvis/Hector 2000, MEA 2003).[18]

Ecosystem services (ES) are the benefits people obtain from ecosystems, according to the Millennium Ecosystem Assessment (MEA 2003): "Ecosystem services can be classified as provisional (eg fibre, food, freshwater production), regulative (eg disease management, climate regulation, freshwater purification), supportive/processes (eg nutrient cycling, pollination, soil formation) and cultural (eg cultural/religious/spiritual, aesthetic, educational, recreational)."

Nature's Contributions to People (NCP), according to IPBES (2019), "are all the contributions, both positive and negative, of living nature (i.e. diversity of organisms, ecosystems, and their associated ecological and evolutionary processes) to the quality of life for people. Beneficial contributions from nature include food provision, water purification, flood control, and artistic inspiration, whereas detrimental contributions include disease transmission and predation that damages people or their assets. Many NCP may be perceived as benefits or detriments depending on the cultural, temporal, or spatial context." IPBES (2019) identifies 18 NCPs grouped according to the contribution they make to people's quality of life: regulating, material and non-material NCP (see Figure A1 for full list and global trends).

[17] UN 1992: Convention on Biodiversity. https://www.cbd.int/doc/legal/cbd-en.pdf.
Gaston K.J.; Spicer J.I. 2004: Biodiversity: An Introduction. Blackwell Publishing Oxford UK.
[18] Purvis A., Hector A. 2000: Getting the measure of biodiversity. Nature. Vol. 405 11 May 2000, 212-219.
MEA (Millennium Ecosystem Assessment) 2003. Ecosystems and Human Well-being: A Framework for Assessment. Washington D.C.: Island Press.

Figure 3: Interplay of biodiversity and ecosystem services with society and the economy.



Source: Swiss Re Institute, adapted from Maes 2013[19]

Why focus on ecosystem services?

It matters to ecosystem services which species are abundant and how many species there are. Unlike other goods, many ecosystem services are not valued or traded in markets at readily observable prices. How we use ecosystems – the way we run our societies and our economies – often takes supplies and the renewal of ecosystems for granted. Degradation of ecosystem services could be significantly slowed down or even reversed if the role of biodiversity and its full contribution to economic production were an integrated part of decisions made by governmental entities, companies, and other stakeholders (Paul et al 2020)[20]. Species loss can destabilise ecosystems and can suddenly disrupt the flow of benefits from nature to people because of the interconnection of species and ecosystems (Hooper et al 2012; Cardinale et al 2012).[21,22]

[19] Maes et al. 2013. Mapping and Assessment of Ecosystems and their Services. An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020. Publications office of the European Union, Luxembourg.
[20] Paul C., Hanley N., Meyer S.T., Fürst, C., Weisser W.W., Knoke T. 2020: On the functional relationship between biodiversity and economic value. Science Advances 29 January 2020: Vol. 6, no. 5, eaax 7712.
[21] Hooper D.U., Adair C., Cardinale B.J., Byrnes, J. 2012: A global synthesis reveals biodiversity loss as a major driver of ecosystem change. Nature 486 (7401): 105-8, June 2012.
[22] Cardinale B.J., Gonzalez A., Duffy J.E., Hooper U. 2012: Biodiversity loss and its impact on humanity. Nature 486 (7401): 59-67, June 2012.

Species redundancy is a measure for ecosystem resilience in a time of ongoing decline as certain species can replace the underlying functions of others facing extinction. This relationship does not last forever, however, given the potential risk of ecosystem services malfunctioning or abrupt environmental changes. The currrent (evolving) scientific consensus is that biodiversity-ecosystem functioning relationships are positive concave[23], with a declining marginal contribution of the next important species taking a role (Paul et al 2020). However, the individual links between biodiversity, ecosystem functions and services that relate to economic value contributions are highly variable. These links depend on trade-offs between different ecosystem services and between expected economic returns and risks. They also depend on (i) different utility functions that vary across sociodemographic classifiers of individuals and their preferences, and on (ii) environmental and economic policy traditions and trajectories that vary between countries (Paul et al 2020).

2.1 Reasons for biodiversity decline and ecosystem function degradation

The interaction of many factors leads to the decline of biodiversity and the degradation of ecosystems. The most notable direct drivers are (IPBES 2019) (i) habitat and land use change, including fragmentation of forests and expansion of infrastructure and other built up areas; (ii) invasive species that establish and spread outside their normal geographic distribution; (iii) overexploitation of natural resources; (iv) pollution – particularly from excessive fertilizer use leading to high levels of nutrients in soil and water; and (v) climate change. Table 1 classifies these drivers in greater detail.

[23] With ecosystem services functionality up to 100% on the x-axis and species diversity increasing on the y-axis.

Table 1: Biodiversity and ecosystem services threats classification

1. Residential and commercial development
- Housing and urban areas
- Commercial and industrial areas
- Tourism and recreation areas

2. Agriculture and aquaculture
- Annual and perennial non-timber crops
- Wood and pulp plantations
- Livestock farming and ranching
- Marine and freshwater aquaculture

3. Energy production and mining
- Oil and gas drilling
- Mining and quarrying
- Renewable energy

4. Transportation and service corridors
- Roads and railroads
- Utility and service lines
- Shipping lanes
- Flight paths

5. Biological resource use
- Hunting and collecting terrestrial animals
- Gathering terrestrial plants
- Logging and wood harvesting
- Fishing and harvesting aquatic resources

6. Human intrusions and disturbance
- Recreational activities
- War, civil unrest and military exercises
- Work and other activities

7. Natural system modifications
- Fire and fire suppression
- Dams and water management / use
- Other ecosystem modifications
- Removing / reducing human maintenance

8. Invasive and problematic species, pathogens and genes
- Invasive non-native/alien plants and animals
- Problematic native plants and animals
- Introduced genetic material
- Pathogens and microbes

9. Pollution
- Household sewage and urban waste water
- Industrial and military effluents
- Agricultural and forestry effluents
- Garbage and solid waste
- Air-borne pollutants
- Excess energy

10. Geological events
- Volcanoes
- Earthquakes / tsunamis
- Avalanches / landslides

11. Climate change
- Ecosystem encroachment
- Changes in geochemical regimes
- Changes in temperature regimes
- Changes in precipitation and hydrological regimes
- Severe / extreme weather events

Source: IUCN/CMP 2016[24]

[24] IUCN/CMP 2016 (International Union for the Conservation of Nature/Conservation Measures Partnership): IUCN's Classification of Direct Threats (v2.0). CMP-OpenStandards.org. https://cmp-openstandards.org/library-item/threats-and-actions-taxonomies/

The International Union for the Conservation of Nature (IUCN) regularly assesses the conservation status of species. Currently, more than 31 000 or 27% of the species the IUCN has assessed are threatened with extinction.[25] IPBES (2019) estimates that of the 8.1 million animal and plant species on Earth – with the vast amount of these species not yet known to humans – roughly 1 million are threatened with extinction.[26]

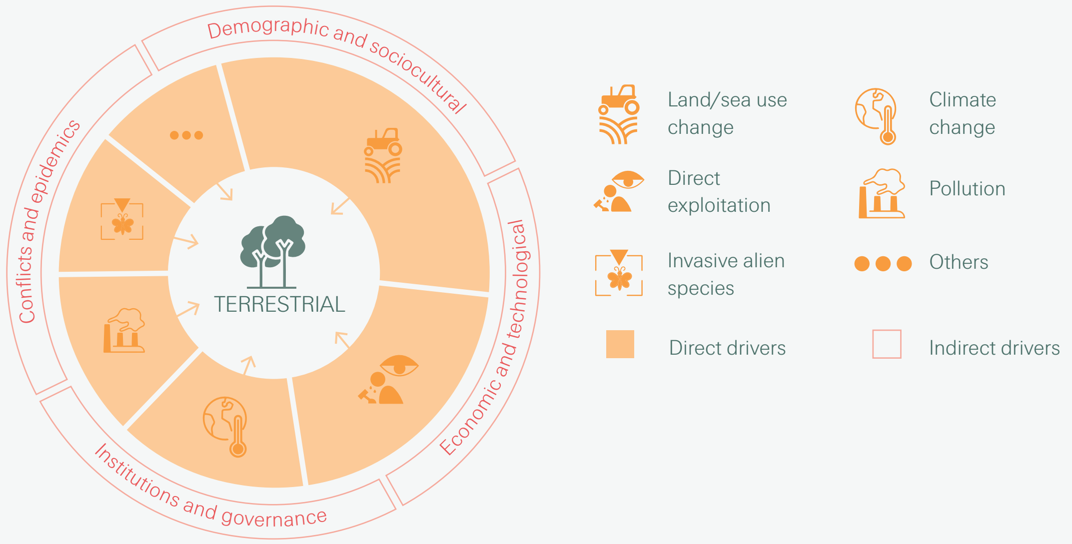
To our knowledge, global monitoring of ecosystem services has not been as comprehensive or regular as biodiversity monitoring, at least in regard to threatened species or species abundancy. IPBES (2019) has assessed how global trends in the past 50 years have changed nature's capacity to provide benefits to humans (see Figure A1). The majority of the 18 services studied shows a decline in contributions. Many of these services cannot be fully substituted with others. Even if substitution were possible, if often comes at a higher cost or with negative external effects. For example, using chemical pesticides instead of natural pest control may damage the health of humans, animals, and plants (IPBES 2019, DNB 2020).

Changes in climate have significantly impacted biodiversity and ecosystems in certain regions. As climate change becomes more severe, harmful influences on ecosystem services are expected to outweigh potential benefits (such as longer growing seasons) in most regions of the world (IPCC 2014[27] and IPCC 2019[28]). Turner et al. (2020)[29] suggest that climate extremes will lead to abrupt changes in some ecosystem dimensions well before policies designed to address slowly developing average conditions have been implemented. At the same time, science has not yet fully understood these potential abrupt changes in ecosystem services.

Indirect drivers such as human population, economic activity, technology, as well as socio-political and cultural factors also affect biodiversity. Figure 4 visualizes the indirect and direct drivers that lead to ecosystem services degradation with some concrete examples of decline.

[25] https://www.iucnredlist.org/.
[26] https://ipbes.net/news/how-did-ipbes-estimate-1-million-species-risk-extinction-globalassessment-report.
[27] IPCC (Intergovernmental Panel on Climate Change) 2014: Climate Change 2014. Impacts, Adaptation and Vulnerability. Part B: Regional Aspects. Retrieved 29. June 2020. https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-PartB_FINAL.pdf
[28] IPCC (Intergovernmental Panel on Climate Change) 2019: Climate Change and Land. https://www.ipcc.ch/site/assets/uploads/sites/4/2019/11/03_Technical-Summary-TS.pdf and https://www.ipcc.ch/site/assets/uploads/sites/4/2020/02/SPM_Updated-Jan20.pdf
[29] Turner M.G., Calder, W.J., Cumming G.S., Hughes T.P., Jentsch, A., LaDeau, S.L., Lenton, T.M., Shuman, B.N., Turestsky, M.R., Ratajczak, Z., Williams, J.W., Willaims, A.P., Carpenter, S.R. 2020: Climate change, ecosystems and abrupt change: science priorities. Phil. Trans. R. Soc. B 375: 20190105. 8 August 2019. For further detail see McDowell N.G. et al 2013: Evaluating theories of drought-induced vegetation mortality using a multimodel-experiment framework. New Phytol. 200, 304-321; and Ratajczak Z. et a. 2017: The interactive effects of press/pulse intensity and duration on regime shifts at multiple scales. Ecol. Monographs 87, 198-218.

Figure 4: Indirect and direct drivers and examples of ecosystem services degradation



Examples of declines in nature

47% Ecosystem extent and condition
Natural ecosystems have declined by 47 per cent on average, relative to their earliest estimated states

25% Species extinction risk
Approximately 25 per cent of species are already threatened with extinction and/or decline in most animal and plant groups studied

23% Ecological communities
Biotic integrity – the abundance of naturally present species – has declined by 23 per cent on average in terrestrial communities (since prehistory)

82% Biomass and species abundance
The global biomass of wild mammals has fallen by 82 per cent (since prehistory). Indicators of vertebrate abundance have declined rapidly since 1970

Source: Adapted from IPBES 2019

2.2 Biodiversity loss and ecosystem services degradation: impact on the economy and financial services

Since the late 1990s, economists have better understood the essential contributions of nature to functioning economies and societies (Costanza et al 1997[30] and 2014[31], TEEB 2012). Costanza et al (2014) estimate that global ecosystem services provide annual benefits in the range of USD 125–140 trillion in 2011.[32] Specific examples range from the global annual value of seagrass nutrient cycling of USD 1.9 trillion to a USD 235–577 billion global annual market value of animal pollinated crops to further country specific examples.[33] Table 2 displays concrete examples (OECD 2019).

Table 2: Estimated values of selected biodiversity and ecosystem services[34]

Scale	Good or service	Estimated annual value
Global	Seagrass nutrient cycling	USD 1.9 trillion
Global	Value of animal pollinated crops	USD 235–577 billion
Global	First sale of fisheries and aquaculture	USD 362 billion
Global	Coral reef tourism	USD 36 billion
Europe	Services from the European protected areas network (Natura 2000)	EUR 223–314 billion
Canada	Value of commercial landings from marine and freshwater fisheries	CAD 3.4 billion
France	Recreational benefits of forest ecosystems	EUR 8.5 billion
Germany	Direct and indirect income from recreational fishing	EUR 6.4 billion
Italy	Habitat provision	EUR 13.5 billion
Japan	Water purification from tidal flats and marshes	JPY 674 billion
UK	Physical and mental-health benefits of nature	GBP 2 billion
US	Air purification from trees and forests (avoided morbidity and mortality)	USD 6.8 billion

Source: OECD 2019

Biodiversity loss and ecosystem degradation increasingly put these values at risk. The OECD (2019) estimates that between 1997 and 2010, global land cover changes negatively impacted nature by between USD 4–20 trillion annually; and land degradation losses accounted for an additional USD 6–11 trillion per year. These large ranges could be interpreted as a sign that the scientific debate about monetary impact continues.

30 Costanza R., d'Arge R., de Groot R., Farber S., Grasso M., Hannon B., Limburg K., Naeem S., O'Neill R.V., Paruelo J., Raskin R.G., Sutton P., van den Belt M., 1997: The value of the world's ecosystem services and natural capital. Nature 387, 253–260.
31 Costanza R., de Groot R., Sutton P., van der Ploeg S., Anderson S.J., Kubiszewski I., Farber S., Turner R.K., 2014: Changes in the global value of ecosystem services. Global Environmental Change 26 (2014) 152-158
32 This is more than 1.5x the size of the global GDP on 2011. Note that the estimates involve uncertainties and are monetized ,what if' numbers – this means, not all the values are ,marketable' values that would be accounted for.
33 OECD 2019: Biodiversity Finance and the Economic and Business Case for Action. Report prepared for the G7 Environmental Ministers's Meeting 5–6 May 2019.
34 Axa Research Fund (2019) quotes different World Band studies stating that low income communities will suffer most from BES decline.

Investing in biodiversity and ecosystem restoration can reduce the risk of damage from natural catastrophes. According to Barbier (2015), ecosystem restoration (river diversion, marsh creation, accompanied by building of levees and other structures) along the coast of Louisiana would lower expected flood costs by USD 5.3 billion, to USD 18 billion, annually.[35] Globally, an annual investment of USD 5–10 billion into coastal wetlands protection could lower flood-damage payouts by USD 52 billion annually.[36]

Without the fragmentation of coastal mangroves, tsunamis would have less significant impact (Losada et al 2018).[37] And without functioning coral reefs, the flood damages for 100-year storm events would increase by 91% to USD 272 billion, according to Beck et al (2018).[38] Barbier et al. share a further example of the economics of biodiversity: the global seafood industry, with an annual revenue of USD 252 billion, would increase annual profits by USD 53 billion if they invested USD 5–10 billion annually into biodiversity preservation.[39]

Science is making progress to assess how, for example, agriculture or manufacturing depend on and impact certain ecosystem services (Frischknecht et al 2018:62[40], Cabernard et al 2019[41], NCFA 2020[42]). However, the debate about how financial services indirectly influence ecosystems has only just begun (CDC Biodiversité 2019[43], PwC/WWF 2020, DNB 2020).

Businesses, communities, families and individuals suffer as a result of the losses described above. In fact, changes in biodiversity and ecosystems affect companies' license to operate (ecological/physical risks). More far-reaching changes can affect policy, consumer preferences, reputation, and even cost of capital and perceived investor risk (eg TEEB 2012, OECD 2019, DNB 2020).

BES are relevant for re/insurance. Table 3 sets out key areas of relevance as per the different sources and Swiss Re Institute considerations and discussions with stakeholders. Figure 5 provides an overview of risks from BES degradation, including the drivers and the interplay with financial and re/insurance markets. This interplay is conventionally called a transmission mechanism. Through this mechanism – by providing capital or risk protection to their clients in other sectors of an economy – investors, lenders, and insurers enable and influence the activities of those sectors to varying degrees.

[35] Barbier E.B. 2015. Hurricane Katrina's lessons for the World. nature, 20 August 2015. Vol. 524, p. 285–287. Edward B. Barbier refers to the Coastal Protection and Restoration Authority of Louisiana: Louisiana's Comprehensive Master Plan for a Sustainable Coast. Office of Coastal Protection and Restoration 2012. The 2017 and 2023 plans are available online.
[36] The Conversation. Barbier, E.B., Burgess, J.C., Dean, T.J., online available at https://theconversation.com/why-companies-should-help-pay-for-the-biodiversity-thats-good-for-their-bottom-line-106298.
[37] Losada I.J., Menéndez, P., Espejo, A., Torres, S., Diaz-Simal, P., Abad, S., Meck M.W., Narayan, S., Trespalacios, D., Pfliegner, K., Mucke P., Kirch L. 2018. The global value of mangroves for risk reduction. Technical Report. The Nature Conservancy, Berlin.
[38] Beck M.W., Losada, I.J., Menéndez P., Reguero B.G., Diaz-Simal P., Fernandez F. 2018: The global flood protection savings provided by coral reefs. Nature communications 2018, 9:2186.
[39] See FN 41
[40] Frischknecht R., Nathani C., Alig M., Stolz P., Tschümperlin L., Hellmüller P. 2018. Umwelt-Fussabdrücke der Schweiz. Zeitlicher Verlauf 1996–2015. Bundesamt für Umwelt, Bern. Umwelt-Zustand Nr. 1811: 131 S.
[41] Cabernard, L., Pfister S., Hellweg, S. 2019. A new method for analyzing sustainability performance of global supply chains and its application to material resources. Science of The Total Environment, vol. 684, pp. 164–177, Amsterdam: Elsevier, 2019. DOI: 10.1016/j.scitotenv.2019.04.434
[42] NCFA 2020. „Exploring Natural Capital Opportunities, Risks and Exposure (ENCORE)" tool developed by the Natural Capital Finance Alliance in partnership with UNEP-WCMC. Accessed via https://encore.naturalcapital.finance/en/
[43] CDC Biodiversité 2019, Global Biodiversity Score: a tool to establish and measure corporate and financial commitments for biodiversity, Biodiversity 2050 Outlook: Club B4B +, no. 14

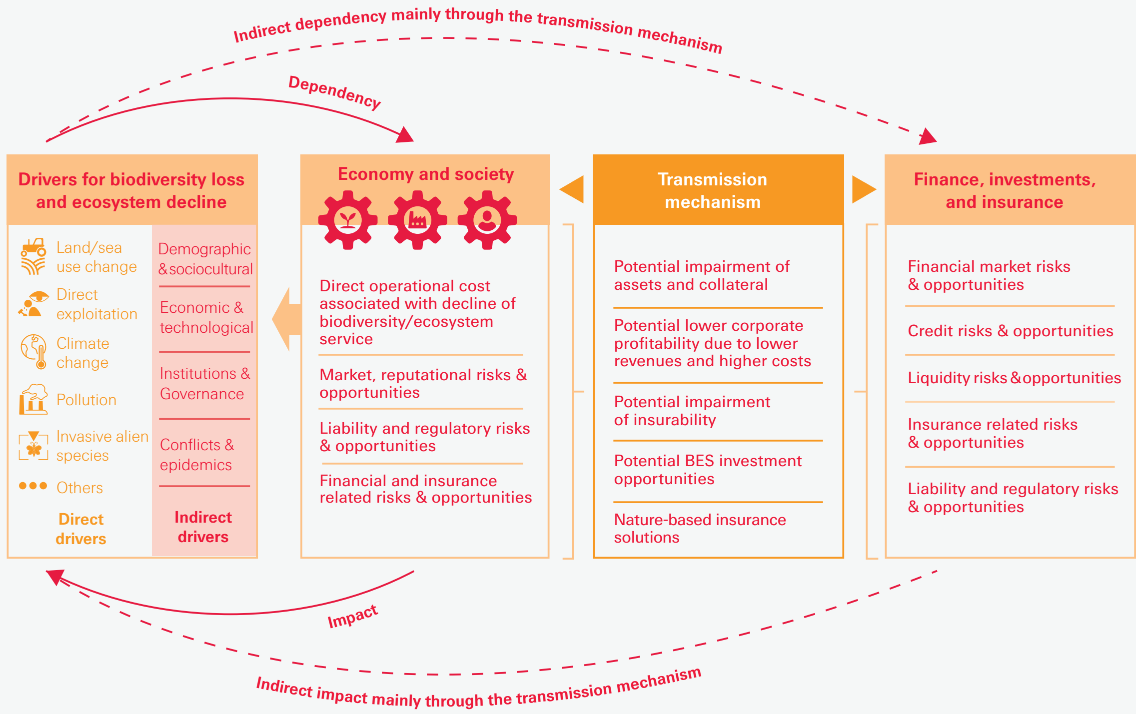
Table 3: Biodiversity and ecosystem services decline: relevance for re/insurance

Category	Consequences
Ecology (= direct operational risks associated with resource dependency, scarcity and quality)	■ Increased cost of raw materials or other resources. The need for alternatives may foster technical progress. ■ Increased supply chain interruption or business continuity risks due to resource scarcity/interruption of services. Specific re/insurance solutions might mitigate some of the risks, revealing opportunities for the re/insurance industry. This fosters technical progress.
Liability, regulatory	■ Parties involved in conflicts might seek legal compensation. Conflicts may arise due to accidental pollution, uncleared usage or property rights, and other reasons. ■ Increased risk of lawsuits as regulators may call for the disclosure and reporting of biodiversity impact. ■ Increased risk of stricter government interventions, for example restrictions on access to and usage of land/sea resources, cap on or limitation of property or usage rights/entitlements. ■ Demand for clean-up and compensation costs. Classical liability re/insurance products might be revisited. ■ New procurement standards and certifications required to conduct business (together with higher transaction costs to assess these standards). ■ New disclosure requirements, licensing and permission procedures. ■ Moratoriums on new permits. ■ Limitations/reductions in resource quotas (eg on fisheries). ■ Impact pricing (eg in analogy to CO_2 charges).
Market, reputation	■ Shifting supply and demand patterns, shifting preferences towards products with reduced environmental impacts or even with a positive contribution, forcing industrial clients to transform their production patterns in order to stay competitive in the long term (and consequently, in order to remain insurance clients). This change creates opportunities for new re/insurance products as well. ■ Requirements for purchaser, such as biodiversity or ecosystem safeguards in supply chains. ■ Enhanced competition due to emerging products/services, technologies and business models. ■ General shifts in public sentiment.

Category	Consequences
Finance, insurance	■ Risks linked to higher re/insurance premiums (or less re/insurance supply/capacity provided) for example for property covers stemming from biodiversity loss or reduced ecosystem services. At the same time, new opportunities for nature-based insurance solutions evolve. ■ Tendency to challenge insurability of certain risks, eg the more the risks depend on BES, the more they negatively impact BES, and the more fragile the BES is. ■ Difficulty to access investment capital, more stringent credit requirements, or higher cost of capital for those companies with a higher dependency on or a more negative impact on biodiversity and ecosystems. ■ Loss of investment opportunities in areas which are negatively affected. Evolvement of new investment opportunities into nature-based solutions, 'green' investments, 'green' infrastructure. ■ Depreciation of assets, eg in agriculture and food production.

Source: OECD 2019, DNB 2020, WEF/PwC 2020[44], TEEB 2012, Swiss Re Institute

Figure 5: The interplay between ecology and the economy and the corresponding transmission mechanism to financial services



Source: Swiss Re Institute, adapted from DNB 2020, IPBES 2019, OECD 2019, PwC/WWF 2020, TEEB 2012.

[44] WEF/PwC 2020. Nature Risk Rising. Published by the World Economic Forum in collaboration with PwC, Geneva/Cologny 2020.

DNB (2020) assesses the risks stemming from biodiversity loss and ecosystem services decline on investments held by Dutch financial institutions. The study expands on the dependency factors, developed by NCFA (2020). It models expected financial losses which may result from the loss of ecosystem services. A loss of ecosystem services "would lead to substantial disruption of business processes and financial losses" according to the study (2020:16). The study also analysed indirect dependencies on ecosystem services and concluded that EUR 510 billion, or 36% of the EUR 1.4 trillion in investments held by Dutch financial institutions, is highly or very highly dependent on one or more ecosystem services. This represents the total expected financial losses if ecosystem services were at zero. The exact level of this risk is location specific, since business activities as well as their value chains are spatial.

To understand the location-specific state of ecosystem services, Swiss Re Institute (SRI) has compiled the SRI BES Index by overlaying publicly available data for ten important ecosystems on a 1 km^2 resolution comparable across the whole world.[45] Our vision for the SRI BES Index is to enable the financial services industry to take action that is more sustainable and more supportive of ecosystems. These actions should reduce the risk of socioeconomic systems reaching tipping points, thereby avoiding abrupt environmental change that can lead to irreversible ecosystem losses and unbearable costs to economies.[46]

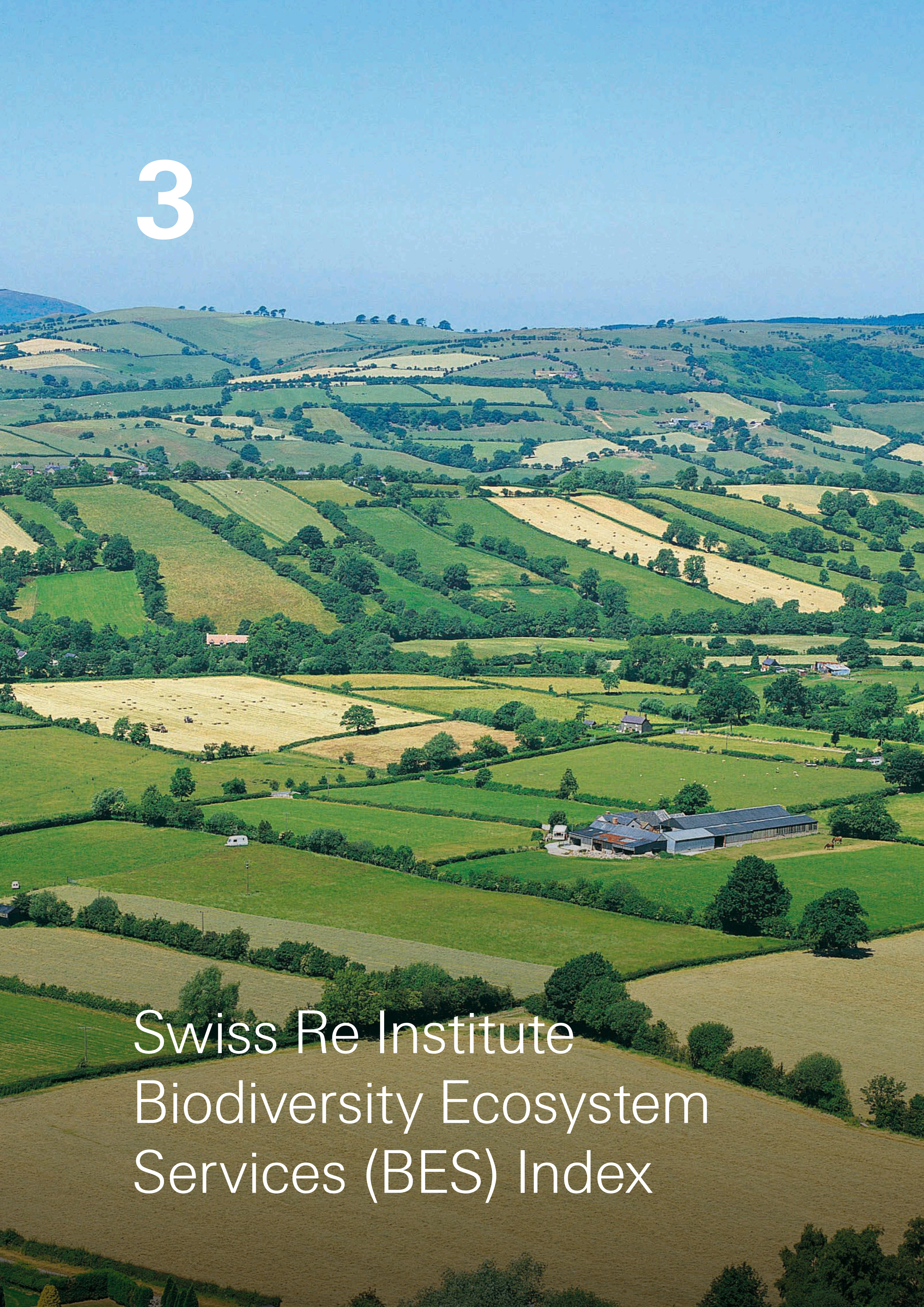
The conservation aspect

The international conservation debate discusses an increase in protected areas of up to 30% of the Earth's surface (CBD 2020).[47] Furthermore, it calls for sound environmental management of important socioeconomic activities within these areas, and ultimately, a reduction in heavy negative impacts on nature. This increase in protected areas seems necessary in order to offer greater, less disturbed habitat for species to survive. The SRI BES Index can also be applied to activities in protected areas. While we consider the state of ecosystems as relevant for risk selection, risk management, and risk pricing on every part on Earth, we call for a conservation-oriented approach, which is all-spatial and integrative, across the entire planet Earth.

[45] For an application with a focus not on the whole world but on World Heritage Sites, see WWF and Swiss Re Institute 2020. Conserving our common heritage. The role of spatial finance in natural world heritage protection. Authored by (alphabetical order) Favier, A, Gysin, L., Garcia-Velez, L., Izquierdo, P., Patterson, D., Retsa, A., Schelske, O., Schmitt, S. Wallquist, L.; London 2020

[46] It is noteworthy to mention that we oriented our work from a methodological perspective on three different, though related concepts. These are (i) the planetary boundaries (Steffen et al 2015) which define safe operating spaces for humanity based on the biophysical processes that regulate the Earth as an ecosystem, (ii) the long tradition of work of conservation biologists on minimum viable populations (Traill et al 2007), and (iii) viewpoints from resource economics, which started with Ciriacy-Wantrup's work on safe minimum standards (1952), in connection to tipping point induced catastrophic cost (Margolis and Naevdal 2008).

[47] CBD 2020. Convention on Biological Diversity. Zero draft of the Post-2020 Global Biodiversity Framework. https://www.cbd.int/doc/c/efb0/1f84/a892b98d2982a829962b6371/wg2020-02-03-en.pdf



3

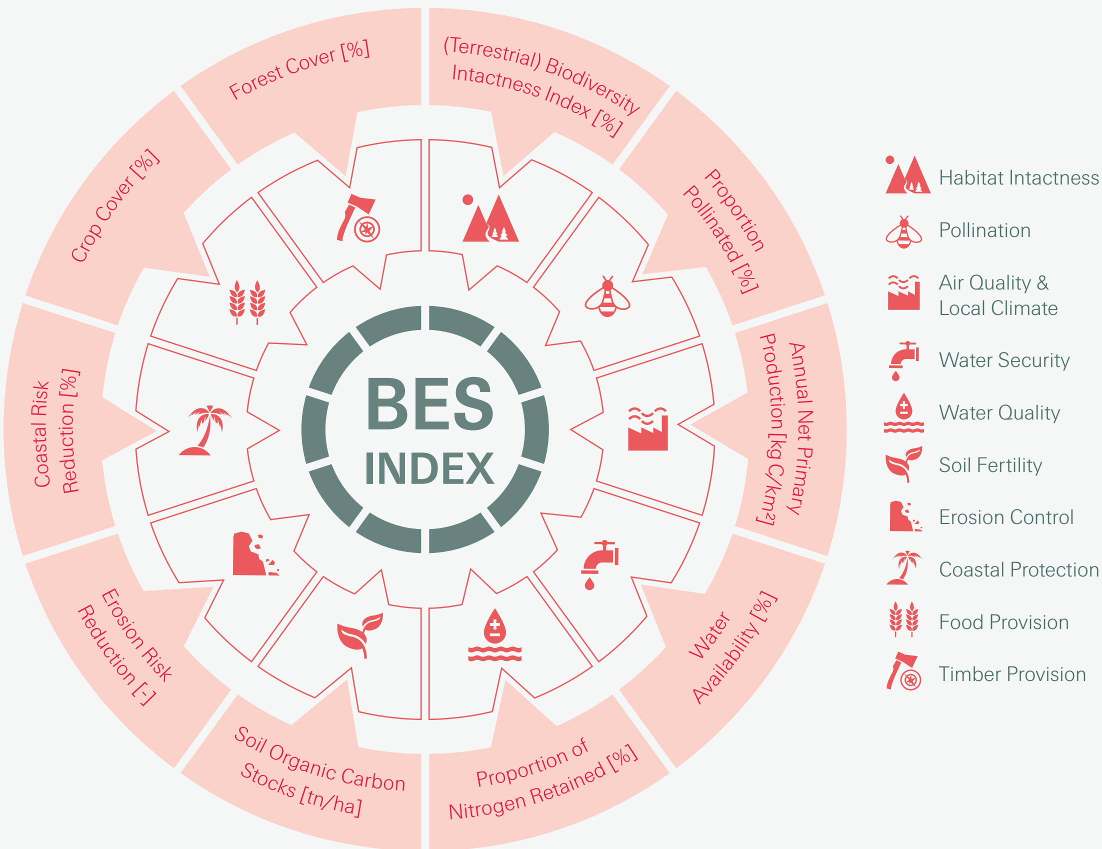
Swiss Re Institute Biodiversity Ecosystem Services (BES) Index

3.1 The state of BES – from a globally comparative assessment on a 1 km^2 resolution to aggregates at country level

Following the IPBES (2019) classification, Swiss Re Institute selected a set of ten BES indicators focusing on terrestrial ecosystems. Our selection is based on the relevance of the BES to re/insurance and different lines of business as well as data availability. While we recognise the significant biological diversity in aquatic and marine ecosystems and its contribution to multiple BES, the focus of our analysis is on terrestrial ecosystems. They represent the majority of risk locations, and a broad range of data resources is widely available for their quantification.

To quantify the provision of BES, we selected an indicator for each service derived from peer-reviewed publications and satellite datasets and mapped these on a global scale. The result is a globally-comparative indicator system of the state of the ten BES (Figure 6). We then aggregated all BES present in each location in the SRI BES Index, which provides an overview of BES for every square kilometer of land. For the aggregation, we calculated a weighted average of the provision of the BES present at each location, assigning equal weights to all BES.

Figure 6: Ecosystem services included in the SRI BES Index



Source: Swiss Re Institute and multiple data sources (see appendix for all details)

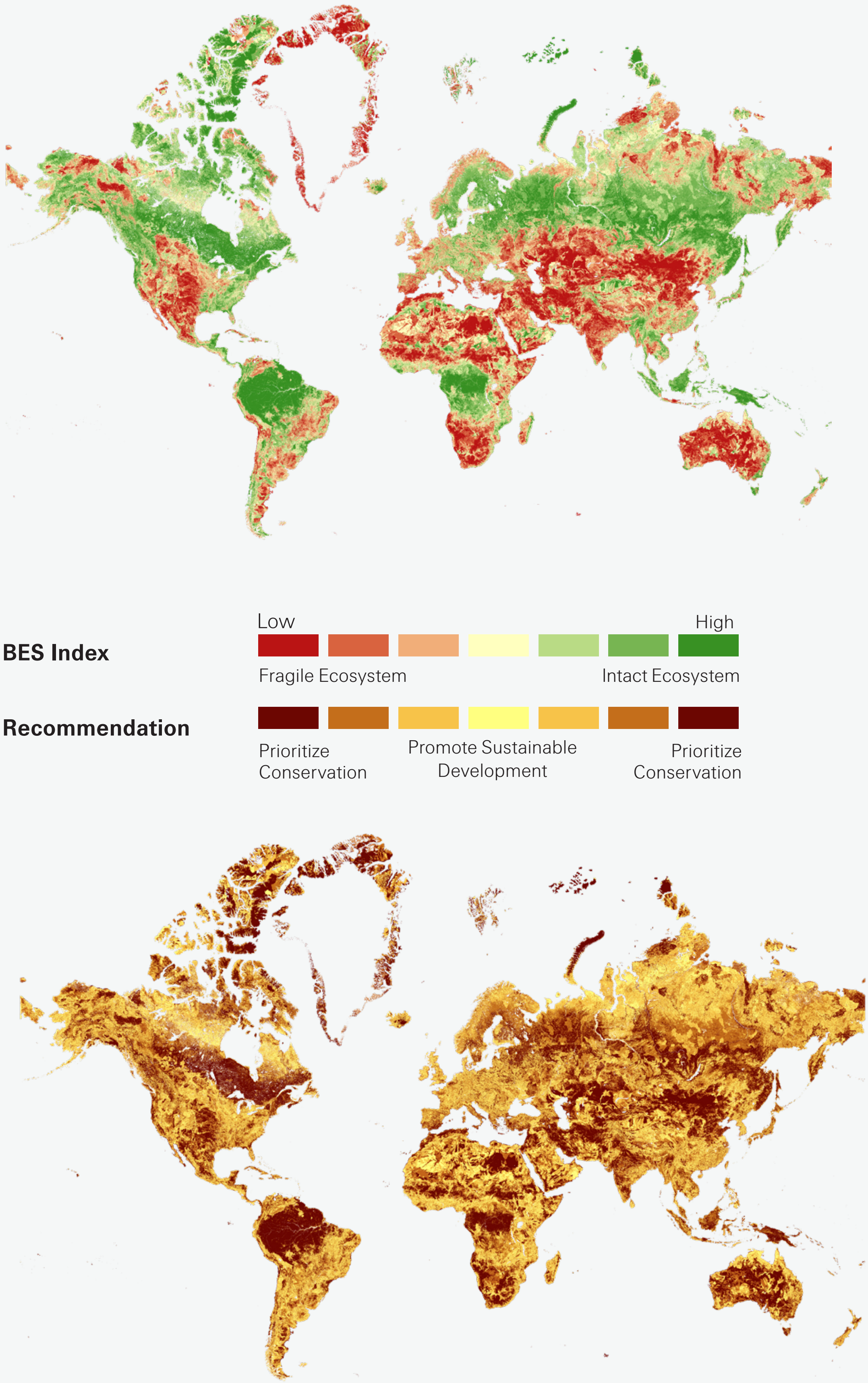
We classify the values of the SRI BES Index in 7 classes globally using the 15th percentile classification. The classes range from "Very High" to "Very Low" and, given the similar values, we define the middle classes as "Moderate". We consider locations with high values of the SRI BES Index ("Very High" BES – upper 15th percentile globally) to be intact ecosystems with significant value for biodiversity and high capacity to provide ecosystem services. Locations with low BES values ("Very Low" class – lower 15th percentile globally) are considered to be fragile ecosystems that have suffered the effects of degradation.[48]

We recognise the global importance of protecting fragile as well as intact types of sensitive locations. Figure 7 shows changes to the SRI BES Index map if we overlay intact and fragile locations. If we had to articulate environmental policy recommendations, it should be a matter of urgency to improve the ecological conditions of the fragile locations and maintain the intact locations. This could be achieved through ecosystem restoration – which is an opportunity for many economic sectors – and/or through a systematic and continuous reduction of negative impacts of socio-economic activities. For all other locations, the focus should be on promoting sustainable development.

Note that Swiss Re is committed to preserving protected areas. Swiss Re does not provide business support to entities or projects that contribute to the conversion or degradation of ecologically sensitive areas. Our Sustainable Risk Framework allows us to respect specifically protected areas including UNESCO World Heritage Sites, High Conservation Value forests, High Carbon Stock forests, wetlands protected by the Ramsar Convention, IUCN listed protected areas and habitats for the species on the IUCN Red list.[49]

[48] Following the argumentation first presented by Lucas and Wilting 2018 and CDC Biodiversité 2019
[49] Swiss Re 2020. Sustainable Business Risk Framework. March 2020.

Figure 7: Global SRI BES Index mapping and overlaying intact and fragile locations

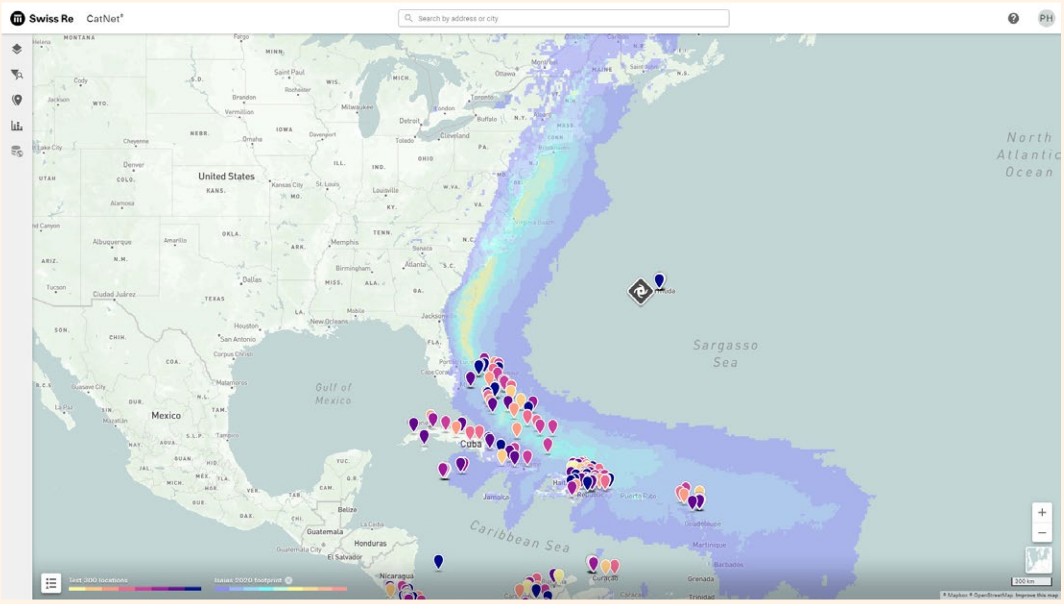


Source: Swiss Re Institute and multiple data sources (see appendix for all details)

Box 3: CatNet®

A dedicated Biodiversity & Ecosystem Services (BES) section in CatNet, Swiss Re's online natural hazard information and mapping system, offers maps based on our BES Index. This tool allows the user to zoom in on individual regions and produce tailor-made maps. Users can import their own coordinates and information into the tool to generate customized data sets. CatNet® is free of charge to Swiss Re clients. A Premium version complements the CatNet® offering with additional features. For further information or to register: www.swissre.com/catnet or contact our CatNet® office at CatNet@swissre.com

Figure box 3-1: CatNet® Isaias footprint and test locations

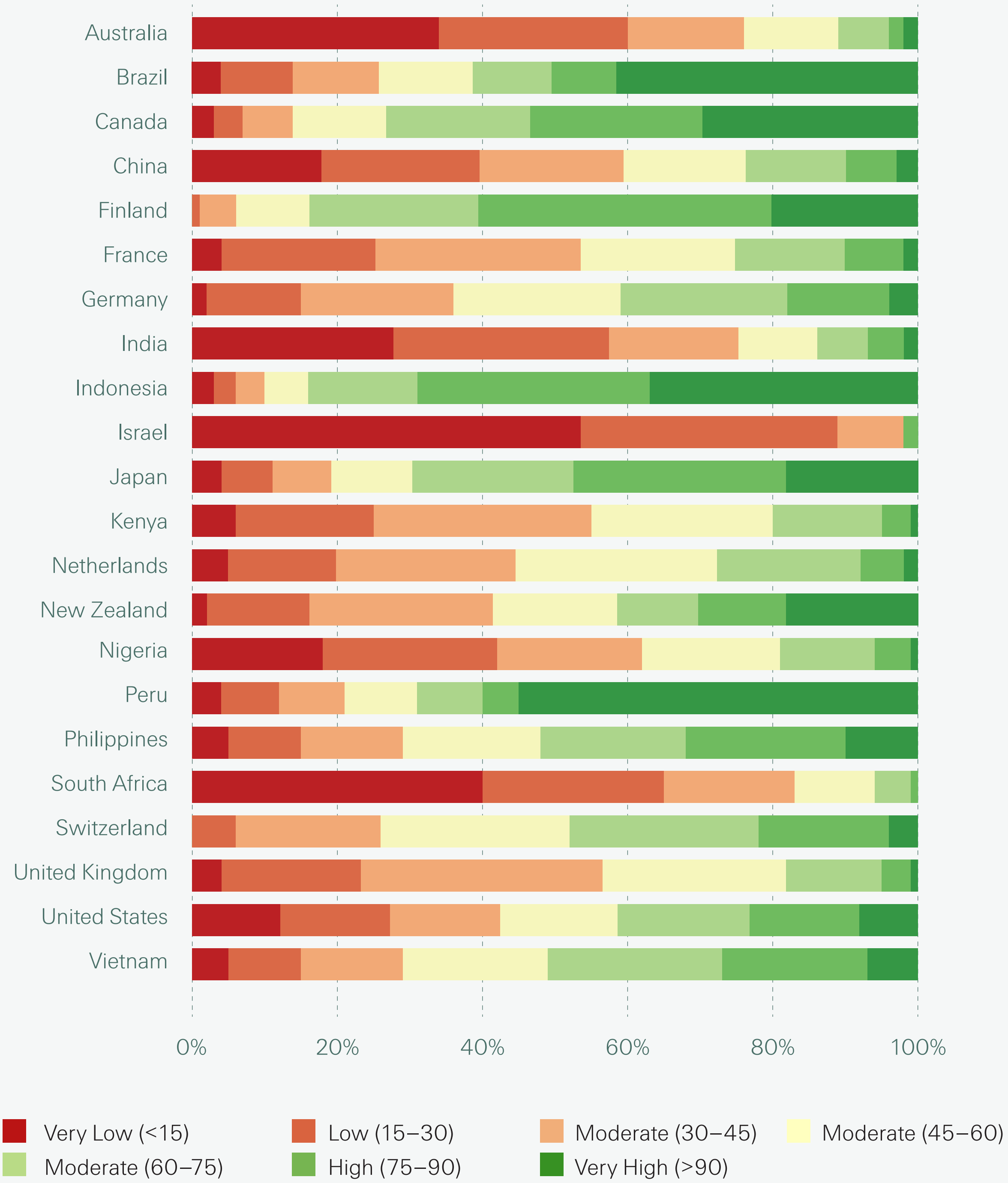


As a further step, we assessed and aggregated the state of the ten ecosystem services on a country level. Figure 8 shows the distribution of the aggregated state of the ten ecosystem services into the seven classes for a selected range of countries for the entire country. This allows for a cross comparison of the state of the ecosystem services in different countries. Appendix A2 includes a list of the top 20 countries with the highest share of intact ecosystems ("Very High" BES Index) and the top 20 countries with the highest share of fragile ecosystems ("Very Low" BES Index). Figure 9 shows the state of each ecosystem service within a country. This allows for further differentiation and cross comparison of individual ecosystem services.

One result, for example, shows that 39 countries (or 20% of all 195 countries) have ecosystems in a fragile state for more than 30% of the entire country area. On the other hand, 30 countries (or 15% of all 195 countries) have ecosystems in an intact state for more than 30% of their entire country area.

We further identify that 60 countries (or 31% of all countries) have ecosystems in a fragile state on more than 20% of their land. 41 countries (or 21% of all) have ecosystems in an intact state on more than 20% of their country area.

Figure 8: SRI BES Index classes at a country level represented as the share of each class for a selection of countries



Source: Swiss Re Institute, various data sources (see appendix).

Figure 9: State of the ten ecosystem services included in the SRI BES Index, aggregated for a selection of countries.

Source: Swiss Re Institute and multiple data sources (see appendix for all details)

3.2 Dependency of economic sectors on BES

The global view

How the ten ecosystem services included in the SRI BES Index contribute to economic activity:

- **Directly:** through **physical input** for production processes (water and timber)
- **Indirectly:** through **conditions** essential for production processes (habitat intactness, pollination, soil fertility, water quality, air quality and local climate)
- **Protective:** protecting production processes against disruptions caused by extreme events (erosion control and coastal protection)

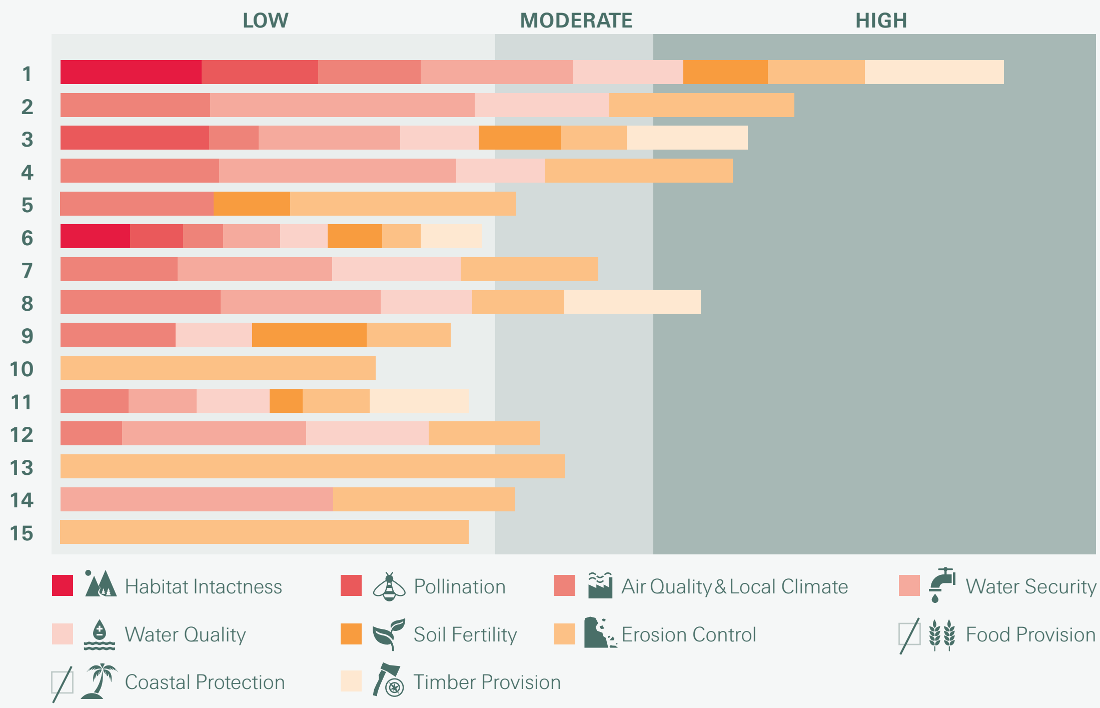
Biodiversity loss poses a threat to economic sectors that depend on the provision of ecosystem services for their operations. Our analysis highlights the economic sectors that depend on nature, the dependencies that are more material, and the exposure each country has to BES decline risks.

To assess how far economic sectors depend on BES, we used the online tool "Exploring Natural Capital Opportunities, Risks and Exposure (ENCORE)".[50] We converted the materiality rankings done by ENCORE, evaluating the dependency of production processes on different ecosystem services on a scale of 1–5, with 1 representing very low materiality (limited loss of functionality and financial impacts) and 5 representing very high materiality (severe loss of functionality and financial impacts).

To align this analysis with the SRI BES Index, we linked the ecosystem services from ENCORE with the BES system based on their definitions and only considered the ecosystem services included in the SRI BES Index. Further, we aggregated the dependency on individual ecosystem services to one value to determine how far each economic sector (NACE[51] Level 1) depends on BES. We consider dependency belonging in the top tercile (values >3.15) as "High" and in the bottom tercile (values <2.3) as "Low". Figure 10 shows these results: agriculture, forestry and fishing and wholesale and retail trade as well as repair of motor vehicles and motorcycles depend on all of the BES assessed. Healthcare depends heavily on water availability for medical operations, while physical infrastructure (eg buildings) is protected by erosion control. In general, erosion control plays a significant role for economic sectors that rely on infrastructure. The dependency of each sector derives from the aggregation of the dependency at a NACE Level 4 (approximately 600 sectoral classes). This allows an analysis of the dependency at a sectoral level based on the industries included in each sector.

[50] Developed by the Natural Capital Finance Alliance in partnership with UNEP-WCMC. Accessed via https://encore.naturalcapital.finance/en/.
[51] NACE Rev2 (Statistical Classification of Economic Activities in the European Community) industry classification

Figure 10: Dependency of economic sectors (NACE Rev2) on the ecosystem services included in the SRI BES Index



1 Agriculture, Forestry & Fishing
2 Mining & Quarrying
3 Manufacturing
4 Electricity, Gas, Steam & Air Conditioning Supply; Water Supply;Sewerage, Waste Management & Remediation Activities
5 Construction
6 Wholesale & Retail Trade; Repair Of Motor Vehicles & Motorcycles
7 Transportation & Storage
8 Accommodation & Food Service Activities
9 Information & Communication
10 Financial & Insurance Activities
11 Real Estate, Professional & Administrative Activities
12 Public Administration & Defence; Compulsory Social Security
13 Education
14 Human Health & Social Work Activities
15 Facilities for Arts, Entertainment, Recreation; Household Activities; Other Activities

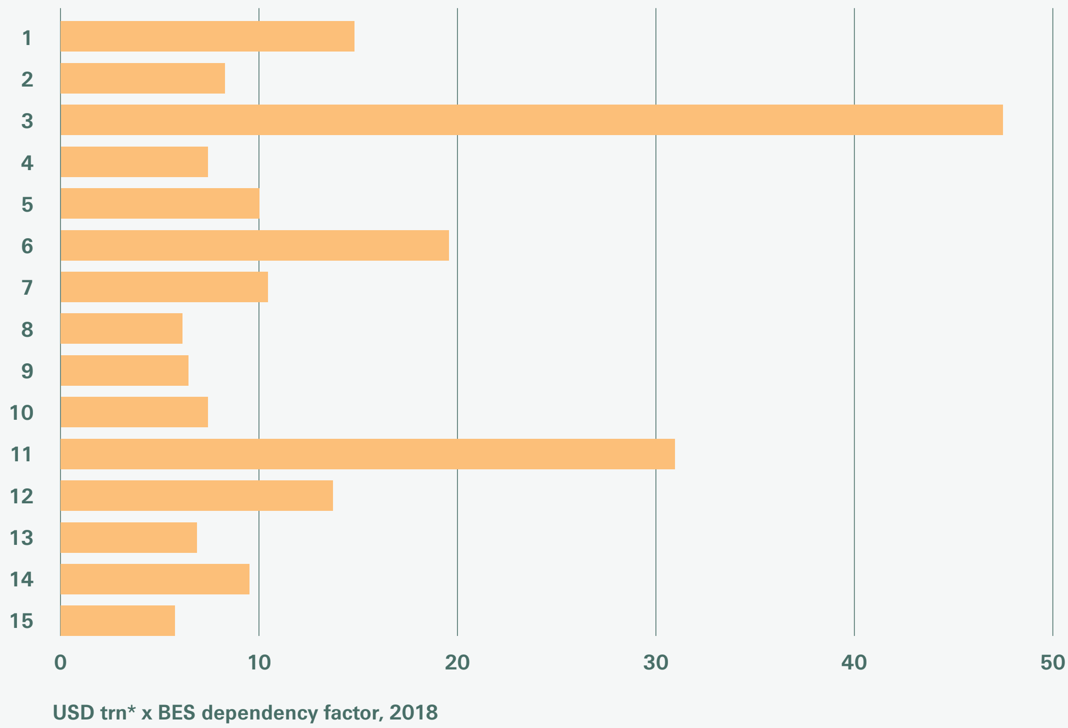
Source: Swiss Re Institute, NCFA 2020, EuroStat 2008

Knowing the global sectoral dependency on BES and the different value contributions of these sectors to the global 2018 GDP (Oxford Economics 2020)[52] allows us a new view, assuming that higher dependency ultimately leads to higher risks. We refer to this view as the "value contribution at risk, due to BES dependency with highest impact on GDP". It is the result of multiplying the percentage of the global GDP contribution of an economic sector (according to NACE Rev2 sector classification)[53] by the BES dependency ranking of that sector (Figure 11).

[52] Oxford Economics 2020 https://data.oxfordeconomics.com. Accessed 09/02/2020
[53] EuroStat Methodologies and Working papers „NACE Rev.2 Statistical classification of economic activities in the European Community", Office for official Publications of the European Communities, 2008

Considering the thresholds mentioned above, 29% of global GDP is highly dependent on BES while 26% of global GDP is moderately dependent on BES. This means, 55% of global GDP is moderately or highly dependent on BES. A sector specific view implies that i) manufacturing, ii) real estate and professional and administrative activities, and iii) wholesale and retail trade, repair of motor vehicles and motorcycles; could be priority sectors if potential risks to the economy were to be mitigated pre-emptively (Figure 11).[54]

Figure 11: BES dependent output potentially at risk, derivation of sector prioritisation from an economic policy perspective



1 Agriculture, Forestry & Fishing
2 Mining & Quarrying
3 Manufacturing
4 Electricity, Gas, Steam & Air Conditioning Supply; Water Supply;Sewerage, Waste Management & Remediation Activities
5 Construction
6 Wholesale & Retail Trade; Repair Of Motor Vehicles & Motorcycles
7 Transportation & Storage
8 Accommodation & Food Service Activities
9 Information & Communication
10 Financial & Insurance Activities
11 Real Estate, Professional & Administrative Activities
12 Public Administration & Defence; Compulsory Social Security
13 Education
14 Human Health & Social Work Activities
15 Facilities for Arts, Entertainment, Recreation; Household Activities; Other Activities

*Value-added output 2018, USD trillion, in constant local currency units (LCU) converted to USD 2015 prices according to Oxford Economics

Source: NCFA 2020, Oxford Economics 2020, EuroStat 2008

[54] While this focuses on dependency, Wilting and Oorschot have provided a deep analysis on the impact of the Dutch economic sectors on biodiversity. See Wilting H.C., van Oorschot M.M.P. 2017. Quantifying Biodiversity Footprints of Dutch Economic Sectors: A Global Supply-Chain Analysis. Journal of Cleaner Production 156 April 2017

The country specific view – the BES boomerang

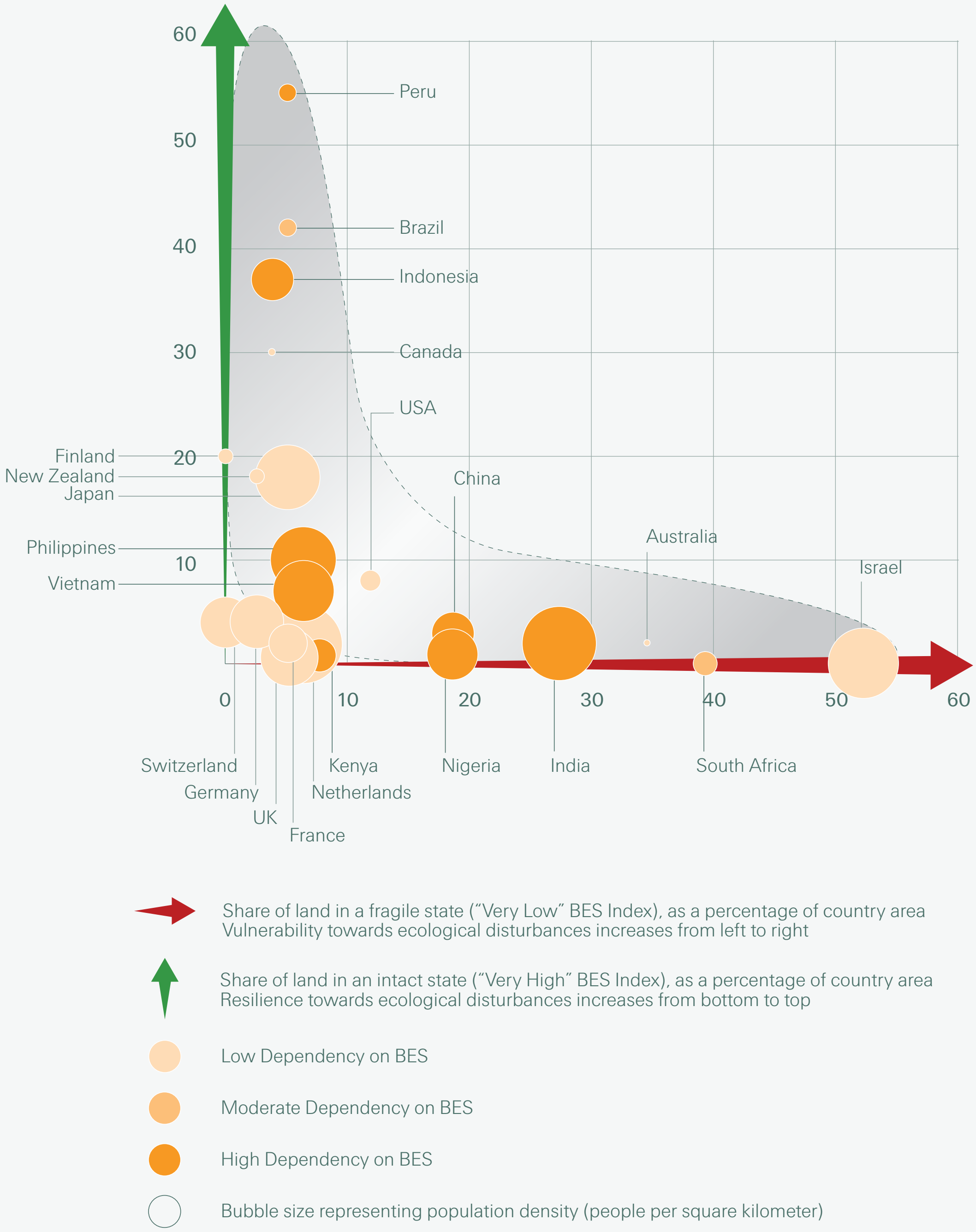
We also assessed the dependency of different national economies on BES. To do this we used the "value-added output as % of GDP" indicator for the year 2018 from Oxford Economics as weights and produced the weighted sum of the dependency on BES from all sectors of a country. A list with the ten most and least GDP-dependent countries can be found in Table A2-3. Finally, we referred to the SRI BES Index map (Figure 2 and Figure 7) for the share of intact and fragile ecosystems in each country and combined them with the economic dependency analysis, adding population density (FAO/World Bank 2020)[55] for 2018 as an indirect driver for BES decline (Figure 12).[56]

This country perspective shows a division between countries with a high share of intact ecosystem services and countries with a high share of fragile ecosystems. Using this approach, we have developed the concept of a global "BES boomerang". In Figure 12, we display a selection of all countries assessed by their share of land in a fragile state (x-axis) and share of land in an intact state (y-axis). The "boomerang" curve is the envelope curve around all countries. To our understanding, countries with a high share of land with a fragile state of ecosystem services are more vulnerable to ecological disturbances. Countries with a high share of land with an intact state of ecosystem services are more resilient to ecological disturbances.

We use the term "boomerang" to underscore the importance of nature conservation for a functioning economy. Boomerangs can strike back and in this case production supplies (eg raw materials, water) are at risk if nature is overexploited and overused. We recommend those countries at the edges of the boomerang place a stronger focus on (i) ecosystem conservation – for those with a high share of intact BES: protect what they have for the future generations, and (ii) restoration – for those with a high share of fragile BES: (re-)build green to avoid abrupt change, regardless of economic dependency and population density.

[55] Food and Agriculture Organization (FAO) and World Bank population estimates, accessed via data.worldbank.org July 6th, 2020.
[56] The matrix and the inherent data behind visualize the basic relations of human-economic footprints on the environment as outlined by for example Vitousek et al. (1997), though there is no data available yet that assesses globally comparative the impact of each driver as classified by IUCN (2016) or IPBES (2019) on each km^2 on Earth.

Figure 12: Country profiles for a selection of countries showing the share of fragile and intact ecosystems and the dependency of the country's economy on BES (sectoral dependency weighted with the share of each sector in country's 2018 GDP).



Source: Swiss Re Institute BES Index, FAO/World Bank 2020, NCFA 2020, Oxford Economics 2020

Here we provide some examples of how to use Figure 12 to further interpret the results. Box 4 describes potential re/insurance business applications to be supported by the BES Index.

- *Countries with a low share of both intact and fragile BES*
  Switzerland for example has a medium population density and a low GDP-dependency on BES. In order to improve its BES resilience, Switzerland would need to invest more in nature (for example, ecosystem restoration and habitat improvement of already protected areas, integration of ecosystem services into spatial planning, tackling of nitrogen issues, etc.). Despite the low GDP-dependency on BES, which is mainly due to the comparatively low share of agriculture in the Swiss GDP, countries like Switzerland are not 'safe havens' in regard to ecological or other disturbances. Examples are increasing landslide risks due to melting permafrost in the Alps, or increasing groundwater pollution in the farming areas.

  Vietnam, as another example, with a slightly higher population density than Switzerland, has a much higher GDP-dependency on BES. Diversifying its economy is an area of concern for Vietnam and keeping a low dependency on food imports at the same time. It is important that BES do not become more vulnerable.

- *Countries with a high share of intact and a small share of fragile BES*
  From an economic perspective, these countries can feel 'safe' in terms of potential BES shocks if their GDP does not depend that much on BES (bubble in light orange color), and their population density is low (small bubble). Japan, for example, has vast areas of intact habitat and its economy relies on secondary and tertiary sectors. The majority of the Japanese population is concentrated in large urban areas, however, and is exposed to natural catastrophes like earthquakes and tropical cyclones, which are not included in BES shocks.

  If a country's economy is highly dependent on BES and at the same time it is densely populated, measures to better cope with population density should be accompanied by a diversification of sectoral economies to become less dependent on natural resources (eg in Indonesia).

- *Countries with a high share of fragile and a low share of intact BES*
  Countries like India or Nigeria with a high population density (large bubble) and a high GDP dependency on BES should immediately tackle potential BES shocks. Countries like Australia (low GDP dependency on BES, low population density) on the other hand should prepare for ecologically driven disturbances – and look for opportunities in ecosystem services improvements and restoration. A long-term policy goal could be to first become less vulnerable and then 'move' towards the area where for example Japan is positioned.

Box 4: SRI BES Index business applications

Use BES for location known single-risks

Overlaying BES with single-risks can give first hand insights if an insured operates in degraded or pristine ecosystems or if an industrial activity is dependent on BES in a given location. A location-specific view can also show where BES are already limited, such that future operations could become more vulnerable to business interruption. Furthermore, it can point out where property values could be protected by BES against natural hazards.

Provide risk intelligence

The different indices identify hotspots (either where fragile/threatened or intact). It is possible to overlay them with protected areas (WWF/Swiss Re Institute 2020).[57]

Develop nature-based insurance solutions

BES can form the basis for nature-based insurance solutions (Seddon et al 2020).[58] Examples are nature-based clean water in water stressed areas; restocking fisheries through mangrove restoration; or restoring degraded land to agricultural land by restoring soil. Furthermore, a screening and prioritization of locations where ecosystem services mitigate natural hazards.

Enable nature-related financial disclosures

Quantifying BES dependencies and BES impacts support this upcoming re/insurance activity.[59]

[57] WWF and Swiss Re Institute 2020. Conserving our common heritage. The role of spatial finance in natural world heritage protection. Authored by (alphabetical order) Favier, A, Gysin, L., Garcia-Velez, L., Izquierdo, P., Patterson, D., Retsa, A., Schelske, O., Schmitt, S. Wallquist, L.; London 2020.

[58] Seddon N., Chausson A., Berry P., Girardin C.A.J., Smith A., Turner B. 2020. Understanding the value and limits of nature-based solutions to climate change and other global challenges. Phil. Trans. R. Soc. B. 375: 20190120. https://royalsocietypublishing.org/doi/10.1098/rstb.2019.0120

[59] In July 2020, UNEP FI, UNDP, WWF and global canopy have announced the foundation of Task force on Nature related Financial Disclosures, see https://tnfd.info/

4

Outlook and lessons learned

4.1 Contribution of SRI BES Index to achieving the SDGs and the Aichi – post 2020 framework on biodiversity

The United Nations called 2011–2020 the Decade on Biodiversity and declared five strategic goals and twenty targets to halt biodiversity loss.[60] These are called Aichi-targets on biodiversity (full list in Appendix A1). While many of these goals and targets were not reached, the international community has started to negotiate the Post-2020 Biodiversity Framework.[61]

As of 2018, four out of ten of the 250 largest companies in the world surveyed in an analysis by KPMG (2018)[62] were using the 17 Sustainable Development Goals (SDGs) in reporting to show how their business links to the SDGs. This trend can certainly be observed for the re/insurance industry. As re/insurers further develop sustainability strategies and action plans, they are also exploring how to take action on SDGs a step further, going beyond reporting. They are discussing how to embed the SDGs into their core business strategy, steering decisions and key performance indicators.[63]

Many re/insurance activities already contribute to achieving the SDGs. The activities and their contribution have seldom (if at all) been described in that way – and this is similar for the Aichi targets. The SDGs and the Aichi targets are industry agnostic and as such, the goals, (sub-) targets and indicators are not re/insurance specific. In addition, while the notion of developing further re/insurance products to address SDGs is being considered by some, the need has not yet been directly addressed by the industry. This is the basis for the newly launched iSDG (insurance SDG) initiative by the UNEP FI's PSI, along with Swiss Re and other peer PSI signatories in July 2020.

The SDGs seek to cover the multiplicity of sustainability – environmental, social, economic – many aspects of which contribute to, or are dependent on, BES. The Aichi targets seek to cover the multiplicity of biodiversity and ecosystem services. We show links between twelve SDGs and the ten ecosystem services included in the SRI BES Index.[64] It is already clear by that number, just how important BES are to achieving the goals by 2030.

A key question is: how do we, as the re/insurance industry, integrate achieving the SDGs into business strategy and decision-making? This starts with mapping and prioritising the BES-linked SDGs. First, companies need to become aware of how their business does or does not support or even harm a particular SDG. Furthermore, identifying tradeoffs is interesting, eg if an activity supports climate action but causes harm to life on land.

Then, a process of defining an action roadmap and metrics for success is required, all with the target date of 2030. Awareness is a key step and the SRI BES index can be an invaluable educational tool in this respect. It can also form the basis for decision-making on which activities to proceed, amend or halt, in which locations. Indeed, Wood et al (2018)[65] state that making ecosystem services tangible is a critical step towards successful inclusion into policy and planning.

[60] https://www.cbd.int/sp/targets/
[61] https://www.cbd.int/conferences/post2020
[62] KPMG, 2018. How to report on the SDGs: what good looks like and why it matters.
[63] UN Environment Programme's Principles for Sustainable Insurance Initiative and Swiss Re 2020 event series about Sustainable Leadership in Insurance, see https://www.swissre.com/institute/conferences/sustainability-leadership-in-insurance.html#05
[64] Depending on one's perspective some authors cite a link to ecosystem services with all 17 SDGs. See Reyers, B., Selig, E.R. 2020. Global targets that reveal the social–ecological interdependencies of sustainable development. Nat Ecol Evol 4, 1011–1019 (2020). https://doi.org/10.1038/s41559-020-1230-6
[65] Wood S. et al., 2018. Distilling the role of ecosystem services in the Sustainable Development Goals. Ecosystem Services 29 (2018) 70-82

BES linked SDGs that many re/insurers currently prioritise are Zero Hunger, Good Health and Well-being, Clean Water and Sanitation, Sustainable Cities and Communities, and Climate Action. These are all SDGs that rely heavily on BES. Currently though, it seems that re/insurers generally do not prioritise Life on Land or Life Below Water.[66]

The problem of SDGs 14 and 15: Biodiversity and ecosystem service conservation form the basis of SDGs 14 'Life below water' and 15 'Life on land', and their contribution to ecosystem services and human wellbeing underpins the achievement of all other goals (see Figure 13 and ICSU ISSC 2015).[67]

Figure 13: The biosphere SDGs underpin all other SDGs

Source: Kok et al. 2017, Lucas and Wilting 2018, Stockholm Resilience Centre 2018[68]

[66] UN Environment Programme's Principles for Sustainable Insurance Initiative and Swiss Re 2020 event series about Sustainable Leadership in Insurance, see https://www.swissre.com/institute/conferences/sustainability-leadership-in-insurance.html#05

[67] ICSU ISSC. 2015. Review of Targets for the Sustainable Development Goals: The Science Perspective. Paris: International Council for Science (ICSU).

[68] Kok, M., Sewell, A., de Blois, F., Warrink, A., Lucas P., van Oorschot, M. 2017 People and the Earth. International Cooperation for the Sustainable Development Goals in 23 Infographics. PBL Netherlands Environmental Assessment Agency 2017. https://data.pbl.nl/api/embed/infographic/data/en/dgis17/003i/05/003i_dgis17_05_en.pdf.
Lucas P., Wilting H. 2018. Towards a safe operating space for the Netherlands. Using planetary boundaries to support national implementation of environmental-related SDGs. PBL Netherlands Environmental Assessment Agency Den Hague 2018.
Stockholm Resilience Centre. How Food Connects all the SDGs: Johan Rockström and Pavan Sukhdev Present New Way of Viewing the Sustainable Development Goals and How They Are All Linked to Food. https://www.stockholmresilience.org/research/research-news/2016-06-14-how-food-connects-allthe-sdgs.html.

As stated by Zeng et al (2020)[69], the currently prescribed SDG framework´s efficacy in protecting biodiversity is uncertain. For several reasons social and economic issues are favored over environmental ones. The two directly linked SDGs (Life below Water, Life on Land) often receive the least attention and the lowest prioritisation (KPMG 2018). The SRI BES Index may well serve as a tool to help address this; especially as better data and analysis are key identified reasons for this shortcoming (Zeng et al 2020). Given that the two biosphere goals of Life on Land and Life below water underpin all other SDGs (see Figure 13), we propose that they should be explicitly considered when re/insurers prioritise the SDGs they will focus on.

The SDGs and the Aichi Strategic Plan are mutually supportive and reinforcing, and therefore the implementation of one contributes to the achievement of the other (CBD/FAO/UNEP/UNDP).[70] In order to better understand how the BES research could contribute to both sets of targets, we assessed the support level for different SDGs by the ecosystem services included in the SRI BES Index. The assessment was based on literature for the mapping of the contribution of BES to achieving targets for 12 SDGs (Wood et al 2018) and the linkages between SDGs and the Aichi Biodiversity Targets. We aggregated the SDG targets and the results show the level of support of each of the ecosystem services for the 12 SDGs, with the maximum representing a strong level of support for all targets assessed in that SDG (Figure 14).

[69] Zeng Y., Maxwell, S., Runting, R. K., Venter, O., Watson, J. E. M., Carrasco, L. R. 2020. Environmental destruction not avoided with the Sustainable Development Goals. Nature Sustainability. DOI: 10.1038/s41893-020-0555-0

[70] Convention on Biological Diversity (CBD), Food and Agriculture Organization of the United Nations (FAO), World Bank Group, United Nations Environment Programme (UN Environment), United Nations Development Programme (UNDP): Biodiversity and the 2030 agenda for sustainable development. Technical Note. Without year. Secretariat of the Convention on Biological Diversity, Montreal, Quebec, Canada. Online available at https://www.cbd.int/development/doc/biodiversity-2030-agenda-technical-note-en.pdf

Figure 14: Strategic CBD biodiversity targets relevancy for the UN SDGs in conjunction with the ten SRI BES Index components

SDG	AICHI*	Habitat Intactness	Pollination	Air Quality & Local Climate	Water Security	Water Quality	Soil Fertility	Erosion Control	Coastal Protection	Food Provision	Timber Provision
1 NO POVERTY	2 6 7 14	100%	67%	67%	100%	67%	67%	67%	67%	100%	100%
2 ZERO HUNGER	4 6 7 13 18	87%	93%	80%	93%	67%	87%	67%	93%	80%	80%
3 GOOD HEALTH AND WELL-BEING	8 13 14 16 18	89%	33%	67%	89%	100%	67%	50%	0%	100%	67%
6 CLEAN WATER AND SANITATION	8 11 14 15	100%	0%	0%	92%	100%	67%	100%	92%	100%	58%
7 AFFORDABLE AND CLEAN ENERGY	5 7 14 15	67%	0%	83%	100%	67%	67%	67%	67%	67%	67%
8 DECENT WORK AND ECONOMIC GROWTH	2 4 6 7 14 16	78%	67%	67%	67%	67%	78%	0%	67%	78%	67%
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	2 4 8 14 15 19	83%	0%	83%	100%	67%	67%	67%	67%	67%	67%
11 SUSTAINABLE CITIES AND COMMUNITIES	2 4 8 11 14 15	87%	56%	77%	80%	80%	67%	67%	73%	67%	67%
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	1 4 6 7 8 19	67%	67%	67%	75%	67%	92%	0%	67%	100%	67%
13 CLIMATE ACTION	2 5 10 14 15 17	100%	67%	100%	100%	100%	100%	67%	100%	100%	100%
14 LIFE BELOW WATER	2 3 4 5 6 7 8 10 11 12 14 15 17 19	94%	0%	94%	67%	67%	67%	67%	67%	94%	67%
15 LIFE ON LAND	2 4 5 7 9 11 12 14 15 16	100%	89%	81%	94%	89%	100%	94%	78%	94%	94%

* **Relevant AICHI Biodiversity Targets**

Habitat Intactness · Pollination · Water Security · Air Quality & Local Climate · Food Provision
Water Quality · Soil Fertility · Erosion Control · Coastal Protection · Timber Provision

Source: Swiss Re Institute, Wood et al 2018, CBD (Footnote 70)

The results show the incredible importance of BES aspects considered in our research to the SDGs and Aichi Targets. Climate Action and Life on Land stand out in particular with very strong levels of support by the ecosystem services under consideration. Clean Water and Sanitation, with its related Aichi targets, is also heavily supported. If re/insurers were prioritising any of the 12 SDGs assessed here and working towards achieving them from either a 'do no harm' or 'contribution towards' perspective, this research may well serve as a useful tool.

The world's sustainability challenges require a multilateral response. Re/insurers can use this research to not only contribute to achieving their industry and company targets, but also to help their governments achieve country commitments to achieving both the SDGs and the Aichi targets laid out in The Strategic Plan.

4.2 Capabilities of the BES Index

Quantifying the state of BES is a contentious issue because it always includes a degree of subjectivity. Certain ecosystem services depend on stakeholder expectations or are relative to a subjectively defined state. Also, more services can be defined than the system we introduced captures, or services can be grouped using different classification methodologies.

Spatial resolution also introduces uncertainty: while a global 1 km^2 coverage is absolutely 'high-resolution' for many services, other services may vary beyond this scale.

Similarly, the quantification of the dependency of economic sectors on BES that we have used here is a general one, assuming similar production patterns as well as similar land-use practices of specific sectors across countries.[71] Agriculture is the best example here. While in general many organic farming practices are seen as having lesser negative impacts on BES in the long term, organic farming has a higher dependency on BES. This is different to more intensive land-use farming practices that would operate, for example, with artificial fertilizer and pesticides – resulting in a gradually lower dependency on BES, but a much higher possible negative impact on BES, and also on climate change.[72]

[71] Wilting et al 2017 and Wilting and van Oorschot 2017 present a model on how to calculate the impact of human consumption respectively the impact of economic sectors on biodiversity loss. Wilting, H.C., Schipper, A.M., Bakkenes, M., Meijer, J.R., Huijbregts, M.A. 2017: Quantifying Biodiversity Losses Due to Human Consumption: A Global-Scale Footprint Analysis. Environmental Science & Technology 2017, 51, 3298-3306. Wilting H.C., van Oorschot M.M.P. 2017. Quantifying Biodiversity Footprints of Dutch Economic Sectors: A Global Supply-Chain Analysis. Journal of Cleaner Production 156 April 2017 DOI: 10.1016/j.jclepro.2017.04.066

[72] The scientific discussion about farming practices has a long tradition. In broad terms, organic farming is seen as more climate friendly, because it usually tries to work without artificial fertilizer nor with pesticides, which absorb a lot of energy to be produced. For an exemplary reference, see Fliessbach, A., Oberholzer, H.R., Gunst, L., Mäder P. 2007 Soil organic matter and biological soil quality indicators after 21 years of organic and conventional farming. Agriculture, Ecosystems & Environment 2007;118:273-84; and Mäder P., Fliessbach A., Dubois D., Gunst L., Fried P., Niggli U. 2002. Soil fertility and biodiversity in organic farming. Science. 2002; 296:169. Billeter et al 2008 show that species richness of birds and vascular plants is negatively associated with fertilizer use. See Billeter, R., Liira J., Bailey D., Bugter R.J.F. 2008. Indicators for biodiversity in agricultural landscapes: a pan-european study. Journal of Applied Ecology 45. January 2008.

Furthermore, country specific export-import relations, respectively cross-country input-output tables connected to all BES in scope, to unfold dependencies on BES in other countries, were not available yet and hence not taken into account.[73]

We are fully aware of the limitations that are inherent in mapping BES and embrace future innovations that will support improvements to the mapping we present here. In order to see how the state of the ecosystem services is developing over time, it would become necessary to repeat building the BES Index periodically, eg every three to five years. As a pre-requisite, the data used would need to be renewed periodically. Any careful interpretation of the BES index values must consider that there is no direct ecological meaning of the index. For example, we are not forecasting if the locations that have been identified as 'low' or 'very low' are collapsing in the near future. However, the index identifies where to become more careful in regard to socioeconomic activities – because these places are at risk. From a country perspective, the identification prioritises where to conduct further local assessments. Here, we re-state that we built the BES Index as a business decision tool for the re/insurance industry.

Acknowledging these limitations should, however, not preventing us from reducing dependencies nor impacts, especially when the BES state is low or very low. The aim here was rather to show that an actor – be it a company or a government – can already today reduce dependency, knowing for example its production facilities and suppliers and observing the state of BES in a given location.

[73] For reference, see Cabernard et al 2019: Cross-country input-output databases linked to BES would contain the information needed to unfold dependencies and impacts along value chains of specific sectors. However, standard calculation routines to track dependencies and impacts are also necessary to be developed and to be agreed on. BES policies should address the many different stages of production until the final output, across sectors and across the globe.

5

Conclusion: knowing where we are today helps to plan for the future

We started this publication with the following numbers: The SRI BES Index shows that 20% of all countries have ecosystems in a fragile state for more than 30% of their entire country area, and that 15% of all countries have ecosystems in an intact state for more than 30% of their entire country area. Furthermore, 55% of global GDP is moderately or highly dependent on BES. The impact on financial assets is also enormous: The Dutch National Bank estimates a staggering EUR 510 billion or 36% of all of investments from Dutch financial institutions would be lost if the ecosystem services underpinning the Dutch economy were no longer available.

These numbers tell us where we currently stand ecologically and economically. We have designed an index that indicates where this dependence is located around the globe. This information contributes to effective decision-making with respect to how to maintain or improve BES.

For any organisation, the BES Index provides a means to assess in any given location:

- The state of BES
- The dependency of economic activity on BES

The findings can guide business owners, for example, in their efforts to reduce their reliance on BES. The same is true for the selection of new locations. Both scenarios will benefit the resilience of operations, which in turn will generate revenues and keep economies running. In addition, it may lead businesses to consider leaner and safer practices when it comes to the usage of BES.

Financial institutions can use the SRI BES Index in a similar way. The price of financing or re/insurance should take BES fragility or intactness into account. Highly BES dependent operations in fragile areas may not have a sustainable future and this knowledge should help decision makers allocate resources accordingly. The price the financial services industry charges for providing capital – be it via investments or re/insurance – should reflect BES risk going forward.

For public entities, the SRI BES Index supports the prioritisation of conservation goals or the amendment of zoning and spatial planning by integrating the state of the ecosystem services into defined areas. For example, the index allows public entities to identify potential ecological scarcities in densely populated urban or sub-urban areas. Further, when it comes to the development of new districts within given settlement areas or the planning of new cities, the SRI BES Index can underscore the need for resource efficiency. It may also support the implementation of conservation or environmental policy with a focus on the relevant Aichi, respectively post-2020, biodiversity framework targets.[74] It can also form the basis for nature-based insurance solutions to be fostered together with the public sector and interested stakeholders. Examples are nature-based clean water in water stressed areas; restocking fisheries through mangrove restoration; restoring degraded land to agricultural land by restoring soil; or a screening and prioritization of locations where ecosystem services mitigate natural hazards.

[74] CBD 2020. Convention on Biological Diversity. Zero draft of the Post-2020 Global Biodiversity Framework. https://www.cbd.int/doc/c/efb0/1f84/a892b98d2982a829962b6371/wg2020-02-03-en.pdf

BES dependency levels not only inform a business owner or public sector entity about the current state of the ecosystem services. Looking ahead, they can also measure if development is moving in the right direction. This means that if the financial services industry includes BES criteria in their decision-making as outlined, the potential economic negative impact on investments as outlined by the DNB should decline over time. That should be the goal to realize a key purpose of re/insurance: to advance societal resilience. As an industry, we do this by identifying opportunities for re/insurance to strengthen societies' ability to bounce back after major setbacks and reignite economic activities.

The latter is also the goal of Swiss Re. We contribute to these goals in two ways:

- By providing re/insurance solutions to help people get back on their feet if disaster strikes; and,
- By sharing our knowledge to avoid disasters that put people at risk.

The SRI BES Index presented here relates to knowledge sharing and reflects SRI's commitment to generating new and innovative risk knowledge. We look forward to working together with you to develop re/insurance solutions that are supportive of biodiversity and ecosystem services – and promote sustainable growth.

Appendix

A1 Supporting information from external sources

Figure A1: Global trends in the capacity of nature to sustain contributions to a good life quality from 1970 to the present.

	Nature's contribution to people	Selected indicator	50-year global trend	Directional trend across regions
Regulation of environmental processes	**1 Habitat creation and maintenance**	Extent of suitable habitat	↓	○
		Biodiversity intacness	↓	○
	2 Pollination and dispersal of seeds and other prapagules	Pollinator diversity	↓	○
		Extent of natural habitat in agricultural areas	↓	○
	3 Regulation of air quality	Retention and prevented emissions of air pollutants by ecosystems	↘	↓↑
	4 Regulation of climate	Prevented emissions and uptake of greenhouse gases by ecosystems	↘	↓↑
	5 Regulation of ocean acidification	Capacity to sequester carbon by marine and terrestrial environments	→	↓↑
	6 Regulation of freshwater quantity, location and timing	Ecosystem impact on air-surface-ground water partitioning	↘	↓↑
	7 Regulation of freshwater and coastal water quality	Extent of ecosystems that filter or add consistent components to water	↘	○
	8 Formation, protection and decontamination of soils and sediments	Soil organic carbon	↘	↓↑
	9 Regulation of hazards and extreme events	Ability of ecosystems to absorb and buffer hazards	↘	↓↑
	10 Regulation of detrimenta organisms and biological processes	Extent of natural habitat in agriciltural areas	↓	○
		Diversity of cometent hosts of vector-bome diseases	↘	○

Directional Trend

Global trends Decrease ↓ ↘ → ↗ ↑ Increase

Across regions ○ Consistent ↓↑ Variable

Levels of certainty Well-established · Established but incomplete · Unresolved

	Nature's contribution to people	Selected indicator	50-year global trend	Directional trend across regions
Material and assistance	11 Energy	Extent of agricultural land – potential land for bioenergy production	↗	↓↑
		Extent of forested land	↘	↓↑
	12 Food and feed	Extent of agricultural land – potential land for food and feed production	↗	↓↑
		Abundance of marine fish stocks	↓	↓↑
	13 Materials and assistance	Extent of agricultural land – potential land for material production	↗	↓↑
		Extent of forested land	↘	↓↑
	14 Medicinal, biochemical and genetic resources	Fraction of species locally known and used medicinally	↘	○
		Phylogenetic diversity	↓	○
Non-material	15 Learning and inspiration	Number of people in close proximity to nature	↓	○
		Diversity of life from which to learn	↓	○
	16 Physical and psychological experiences	Area of natural and traditional landscapes and seascapes	↘	○
	17 Supporting identities	Stability of land use and land cover	↘	○
	18 Maintenance of options	Species'survival probability	↓	○
		Phylogenetic diversity	↓	○

Directional Trend

Global trends Decrease ↓ ↘ → ↗ ↑ Increase

Across regions ○ Consistent ↓↑ Variable

Levels of certainty Well-established | Established but incomplete | Unresolved

Source: IPBES 2019

Aichi Biodiversity Targets[75]

A

Strategic Goal A: Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society

Target 1: By 2020, at the latest, people are aware of the values of biodiversity and the steps they can take to conserve and use it sustainably.

Target 2: By 2020, at the latest, biodiversity values have been integrated into national and local development and poverty reduction strategies and planning processes and are being incorporated into national accounting, as appropriate, and reporting systems.

Target 3: By 2020, at the latest, incentives, including subsidies, harmful to biodiversity are eliminated, phased out or reformed in order to minimize or avoid negative impacts, and positive incentives for the conservation and sustainable use of biodiversity are developed and applied, consistent and in harmony with the Convention and other relevant international obligations, taking into account national socio economic conditions.

Target 4: By 2020, at the latest, Governments, business and stakeholders at all levels have taken steps to achieve or have implemented plans for sustainable production and consumption and have kept the impacts of use of natural resources well within safe ecological limits.

B

Strategic Goal B: Reduce the direct pressures on biodiversity and promote sustainable use

Target 5: By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced.

Target 6: By 2020 all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits.

Target 7: By 2020 areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity.

Target 8: By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity.

Target 9: By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment.

Target 10: By 2015, the multiple anthropogenic pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or ocean acidification are minimized, so as to maintain their integrity and functioning.

C

Strategic Goal C: To improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity

Target 11: By 2020, at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes.

[75] UN Convention on Biological Diversity. https://www.cbd.int/sp/targets/

Target 12: By 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained.

Target 13: By 2020, the genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives, including other socio-economically as well as culturally valuable species, is maintained, and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity.

D

Strategic Goal D: Enhance the benefits to all from biodiversity and ecosystem services

Target 14: By 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable.

Target 15: By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.

Target 16: By 2015, the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization is in force and operational, consistent with national legislation

E

Strategic Goal E: Enhance implementation through participatory planning, knowledge management and capacity building

Target 17: By 2015 each Party has developed, adopted as a policy instrument, and has commenced implementing an effective, participatory and updated national biodiversity strategy and action plan.

Target 18: By 2020, the traditional knowledge, innovations and practices of indigenous and local communities relevant for the conservation and sustainable use of biodiversity, and their customary use of biological resources, are respected, subject to national legislation and relevant international obligations, and fully integrated and reflected in the implementation of the Convention with the full and effective participation of indigenous and local communities, at all relevant levels.

Target 19: By 2020, knowledge, the science base and technologies relating to biodiversity, its values, functioning, status and trends, and the consequences of its loss, are improved, widely shared and transferred, and applied.

Target 20: By 2020, at the latest, the mobilization of financial resources for effectively implementing the Strategic Plan for Biodiversity 2011–2020 from all sources, and in accordance with the consolidated and agreed process in the Strategy for Resource Mobilization, should increase substantially from the current levels. This target will be subject to changes contingent to resource needs assessments to be developed and reported by Parties.

A2 Country rankings

Tables present the share of fragile ("Very Low" BES class) and intact ("Very High" BES class) ecosystems as the area covered by the respective class over the area of the country covered by the BES maps. For the dependency values we include the GDP weighted dependency scaled using min-max scaling to allow comparability. It must be noted for these tables, we only consider the countries for which the GDP decomposition is available from Oxford Economics. The SRI BES Index can aggregate data for 195 countries.

	Country	Population Density 2018 [people per km²]	Share of Fragile Ecosystems in BES Index	Share of Intact Ecosystems in BES Index	GDP Dependency on BES
Top 20 countries with highest share of Fragile BES state	Malta	1 514.5	100%	0%	0.23
	Israel	410.5	53%	0%	0.30
	Bahrain	2 017.3	50%	0%	0.43
	Cyprus	128.7	47%	0%	0.24
	Kazakhstan	6.8	43%	0%	0.54
	South Africa	47.6	40%	0%	0.40
	Greece	83.3	35%	0%	0.41
	Australia	3.3	34%	2%	0.30
	Singapore	7 953.0	33%	0%	0.35
	India	454.9	28%	2%	0.71
	Morocco	80.7	27%	2%	0.71
	Pakistan	275.3	26%	3%	0.88
	Turkey	107.0	24%	1%	0.56
	Mexico	64.9	24%	4%	0.44
	Spain	93.7	23%	1%	0.36
	Belgium	377.4	23%	0%	0.25
	Iraq	88.5	21%	0%	0.75
	Italy	205.4	21%	2%	0.35
	Tunisia	74.4	18%	10%	0.64
	Algeria	17.7	18%	1%	0.70

Table A2-1: Country ranking based on share of fragile ecosystems

Top 20 countries with highest share of Intact BES state	Peru	25.0	4%	55%	0.63
	Colombia	44.8	1%	45%	0.54
	Brazil	25.1	4%	42%	0.41
	Ecuador	68.8	4%	40%	0.65
	Indonesia	147.8	3%	37%	0.80
	Canada	4.1	3%	30%	0.34
	Malaysia	96.0	0%	29%	0.63
	Latvia	31.0	0%	26%	0.36
	Finland	18.2	0%	20%	0.39
	Russia	8.8	4%	19%	0.52
	Sweden	25.0	0%	18%	0.31
	Japan	347.1	4%	18%	0.37
	New Zealand	18.4	2%	18%	0.36
	Estonia	30.4	2%	14%	0.39
	Austria	107.1	0%	13%	0.41
	Angola	24.7	10%	13%	0.53
	Slovenia	103.0	0%	12%	0.47
	Lithuania	44.7	0%	11%	0.45
	Poland	124.0	1%	11%	0.43
	Croatia	73.1	1%	11%	0.43

Table A2-2: Country ranking based on share of intact ecosystems

	Country	Population Density 2018 [people per km²]	Share of Fragile Ecosystems in BES Index	Share of Intact Ecosystems in BES Index	GDP Dependency on BES
Top 10 countries with highest GDP dependency on BES	Kenya	90.3	6%	1%	1.00
	Vietnam	308.1	5%	7%	0.89
	Pakistan	275.3	26%	3%	0.88
	Indonesia	147.8	3%	37%	0.80
	Nigeria	215.1	18%	1%	0.77
	Iraq	88.5	21%	0%	0.75
	Oman	15.6	7%	3%	0.72
	Morocco	80.7	27%	2%	0.71
	India	454.9	28%	2%	0.71
	Algeria	17.7	18%	1%	0.70
Top 10 countries with lowest GDP dependency on BES	Denmark	138.0	10%	0%	0.30
	Switzerland	215.5	0%	4%	0.29
	Netherlands	511.5	5%	2%	0.27
	France	122.3	4%	2%	0.26
	Belgium	377.4	23%	0%	0.25
	United States	35.7	12%	8%	0.24
	Cyprus	128.7	47%	0%	0.24
	Malta	1514.5	100%	0%	0.23
	United Kingdom	274.7	4%	1%	0.21
	Luxembourg	250.2	1%	1%	0.10

Table A2-3: Country ranking based on GDP dependency on BES

A3 Methodological details of the Swiss Re Institute BES Index

Ecosystem services included in the SRI BES Index
Following the IPBES classification, the selection of the ecosystem services included in the SRI BES Index was based on two criteria: the relevance of the BES to re/insurance and different lines of business (LoB), and the data availability at a high resolution globally. Some ecosystem services were excluded from this analysis since they did not meet these criteria; the ecosystem services for "Ocean acidification" and "Medicinal, biochemical and genetic resources" are not considered due to the lack of available global datasets at a resolution consistent with other ecosystem services, while "Energy" was excluded due to its limited business applications. Finally, we do not consider the non-material ecosystem services listed in the IPBES classification.

Here we describe the selected set of ecosystem services included in the SRI BES Index[76], together with the selected indicators for the quantification at a global scale and further assumptions considered.

1. Habitat Intactness

Indicator: (Terrestrial) Biodiversity Intactness Index [%]

Ecosystems are of critical importance for the provision of ecosystem services at a global scale. The alarming trend of habitat change and degradation, mainly due to anthropogenic influence and climate change, alters their capacity in offering the necessary ecosystem services for human well-being. With this ecosystem service we represent the average proportion of natural biodiversity remaining in local ecosystems. The "(Terrestrial) Biodiversity Intactness Index" used represents the modelled average abundance of originally present species, relative to their abundance in an intact ecosystem, after land use change or human impacts.[77] A broad range of species is considered, and human pressures are incorporated as land use, land use intensity, human population density, and proximity to the nearest road.

2. Pollination

Indicator: Proportion Pollinated [%]

The declining trend of wild pollinators in recent years poses a threat for all economic activities depending directly or indirectly on agricultural products. With three out of four of the leading crop types worldwide depending on animal pollination for yield and quality[78], we incorporate an ecosystem service representing the provision of adequate pollination of pollination-dependent crops by wild pollinators in the SRI BES Index. The selected indicator represents the "Proportion Pollinated" as the ratio of the pollinated production (the pollination-dependent production for which pollination needs are met, according to the habitat around farmland) to the pollination-dependent production (the maximum amount of potential production dependent on pollination).[79]

3. Air Quality & Local Climate

Indicator: Annual Net Primary Production [kg C/km^2]

Vegetated areas have the capacity to reduce the concentration of air pollutants by filtering and retaining certain air pollutants in plant parts, thus ensuring a better air quality. Moreover, although forests are considered a major carbon sink on land, ecosystems can sequester and store carbon in vegetation as well, contributing in the reduction of atmospheric concentration of CO_2 and as a result in climate regulation. These functions are provided by well-established vegetation, thus seasonality plays a significant role in the capacity of a vegetated ecosystem to provide this ecosystem service. However, we do not account for the inter-annual variability of the vegetation status and consider the annual average as provided by the selected indicator. More specifically, we use the "Annual Net Primary Production"[80] that defines the rate at which all plants in an ecosystem produce net useful chemical energy, and can be used as a proxy for the state of vegetation.

[76] Description based on IPBES (2019) Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy platform on Biodiversity and Ecosystem Services.
[77] Newbold, Tim, Lawrence N. Hudson, Andrew P. Arnell, Sara Contu, et al. 2016. „Dataset: Global Map of the Biodiversity Intactness Index." In Tim Newbold et al., „Has Land Use Pushed Territorial Biodiversity beyond the Planetary Boundary? A Global Assessment." Science 353 (2016): 288-89. http://dx.doi.org/10.5519/0009936
[78] Swiss Re Institute 2018. Making a beeline for disaster? The decline of pollinators puts agriculture at risk. Authored by Schelske O., Xing L., Wong C., Trepp F., Swiss Re Institute 2018.
[79] Chaplin-Kramer, R. et al., 2019. Global modelling of nature's contribution to people. Science 366, 255-258 (2019). Dataset: Pollination/Nature's Contribution/Current
[80] Running, S., Mu, Q., Zhao, M. (2011). MOD17A3 MODIS/Terra Net Primary Production Yearly L4 Global 1 km SIN Grid V055 [Data set]. NASA EOSDIS Land Processes DAAC accessed via Google Earth Engine (GEE)

4. Water Security

Indicator: Water Availability [%]

Terrestrial ecosystems play a crucial role in regulating water quantity by different processes in the water cycle (evaporation, surface runoff, groundwater recharge etc.). In the SRI BES Index, we focus on the direct provision of freshwater essential for human well-being and most economic activities. As a result, the selected indicator of "Water Availability" is based on the "Baseline Water Stress" of WRI[81] that measures the ratio of water withdrawals to available renewable surface and groundwater at the catchment scale. Water withdrawals include domestic, industrial, irrigation, and livestock consumptive and non-consumptive uses. Available renewable water supplies include the impact of upstream consumptive water users and large dams on downstream water availability. The indicator used is calculated by inverting the "Baseline Water Stress" scores and converted to a 0–100 scale to represent "Water Availability" as a percentage.

5. Water Quality

Indicator: Proportion of Nitrogen Retained [%]

Nutrient loading from anthropogenic sources, particularly agriculture due to the use of fertilizers, has increased dramatically over the past 50 years, leading to increased pollution of terrestrial, aquatic and marine ecosystems. With this ecosystem service we consider the contribution of terrestrial ecosystems in regulating water quality by retaining nitrogen and reducing the level of pollution. The selected indicator of "Proportion of Nitrogen Retained"[82] represents the nitrogen retained due to habitats over the nitrogen load.

6. Soil Fertility

Indicator: Soil Organic Carbon Stocks [tn/ha]

Nature contributes to better soil quality through improving soil biodiversity, mainly by enhancing Soil Organic Carbon (SOC), which is a strong determinant of soil quality, soil health and crop productivity. The world has lost an estimated 8% of soil carbon globally due to land degradation and more than 60% of the remaining soil carbon is found in 10 countries. According to FAO[83], (SOC) has positive effects on soil structure and soil chemical and biological properties that can increase primary production. Thus, higher SOC stocks in the soil indicate higher soil fertility. The quantification of the indicator was based on the SoilGrids™ maps[84]; we summed the soil organic carbon stocks of different soil layers for the first 100cm of soil considering that this depth includes the average root depth of wheat, corn and rice that represent 60% of global crop production.

7. Erosion Control

Indicator: Erosion Risk Reduction [-]

Terrestrial ecosystems have the potential to reduce the incidence and impact of hazards and extreme events. Focusing on erosion, roots can stabilize the abiotic elements of an ecosystem by securing soils and sediments. The selected indicator for the erosion risk[85] (presented in 5 classes) was inverted considering the ability of different habitats to reduce the erosion risk (sheet and rill erosion from rainfall and associated run-off).

[81] World Resources Institute (WRI) Aqueduct® Global Maps 3.0
[82] Chaplin-Kramer, R. et al., 2019. Global modelling of nature's contribution to people. Science 366, 255–258 (2019). Dataset: Water Quality Regulation/Nature's Contribution/Current
[83] FAO 2017. Soil Organic Carbon: the hidden potential. Food and Agriculture Organization of the United Nations Rome, Italy
[84] Hengl T, Mendes de Jesus J, Heuvelink GB, et al. SoilGrids250m: Global gridded soil information based on machine learning. PLoS One. 2017;12(2):e0169748. Published 2017 Feb 16. doi:10.1371/journal.pone.0169748
[85] World Resources Institute. 2016. „Erosion." Global Forest Watch Water

8. Coastal Protection

Indicator: Coastal Risk Reduction [%]

With the ecosystem service of Coastal Protection we consider the contribution of coastal habitats (such as coral reefs, mangroves, seagrass and salt marhes) to mitigate the impacts of flooding and erosion in coasts through the attenuation of storm waves and the shoreline stabilization. The indicator of "Coastal Risk Reduction"[86] represents the mitigation of the flooding and erosion impacts in terms of the difference in coastal risk with and without the coastal habitats present.

For the aggregation of this ecosystem service at a country level (Figure 9) we allocated the benefits of coastal protection from off-land coastal habitats to each country based on the Exclusive Economic Zones (EEZ).[87] The reasoning is that initiatives for the conservation of coastal habitats are taken at a national level for the territory on and off land.

9. Food Provision

Indicator: Crop Cover [%]

Ecosystems provide the ecological conditions needed for the cultivation of food and feed in agricultural fields. Here, we consider the outputs of cultivated land as food and feed contributing to food security and human well-being. We exclude the provision of food from livestock and fisheries and consider agricultural production represented as the "Crop Cover"[88] fraction in cultivated land.

10. Timber Provision

Indicator: Forest Cover [%]

The production of materials extracted from forest ecosystems, such as timber, has increased globally since 1970. These materials impact the quality of life by providing shelter as used in housing, energy, and raw materials for many industries, they create employment and provide income. With the defined ecosystem service of Timber Provision, we focus on the capacity of forest ecosystems to provide timber as a direct input for production and human use. To quantify the maximum capacity of a forest ecosystem to provide timber for harvesting, we consider the indicator of "Forest Cover"[89] defined as the percentage of each 1 km^2 with tree cover (vegetation taller than 5m in height).

The mapped indicators are expressed in different units. To allow comparability between different ecosystem service, we normalize (Min-Max scaling) the values of each service between 0 and 100; the value of 0 indicates that the service is present at a given location but has the lowest value globally.

We then aggregate all ecosystem services present in each location in one index. To build the SRI BES Index, we calculate an unweighted average of the services that are present in each location, thus averaging the individual ecosystem services status using the arithmetic mean. For this general case, we consider all services of equal significance; however, the weights can be adjusted depending on the focus of the analysis. We classify the values of the SRI BES Index in 7 classes; the cut-off points (COP) are calculated using the 7-quantiles (septiles) from the distribution of the index values to divide the range of the distribution into equally sized groups. The classes defined range from "Very Low" and "Low" to "High" and "Very High". Given the close-range values in the middle of the distribution we allocate three classes for "Moderate" values. It must be noted that we consider the tails of the distribution as outliers (SRI BES Index values below 10 and over 70); we exclude these outliers in the calculation of the COP for an un-biased classification of the SRI BES index and then we include them in the "Very Low" and "Very High" class respectively.

[86] Chaplin-Kramer, R. et al., 2019. Global modelling of nature's contribution to people. Science 366, 255–258 (2019). Dataset: Coastal Risk Reduction/Nature's Contribution/Current
[87] Flanders Marine Institute (2019). Maritime Boundaries Geodatabase: Maritime Boundaries and Exclusive Economic Zones (200NM), version 11. Available online at https://www.marineregions.org/ https://doi.org/10.14284/386.
[88] Copernicus Global Land Service: Land Cover 100m: epoch 2015: Globe (Version V2.0.2) (Buchhorn, M. et al., 2019)
[89] Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. "High-Resolution Global Maps of 21st-Century Forest Cover Change." Science 342 (15 November): 850–53. Accessed via Google Earth Engine (GEE)

Since, the SRI BES Index incorporates only terrestrial ecosystems, we have excluded all surface water and oceans from the map using a global map of surface water[90] capturing oceans, lakes and rivers. It must be noted that due to the 1 km^2 of the BES Index, only major rivers are excluded, and smaller rivers are not captured at this resolution.

To represent the state of the ecosystems at a country level (Figure 8) we use the share of BES classes in each country calculated as the number of 1 km grid cell of each class over total the number of grid cells covered by the SRI BES Index. Finally, to calculate the ecosystem services' status at a country level (Figure 9) we calculated the mean value of all 1 km^2 cells of the individual ecosystem services in each country and further standardized them to allow comparability between the ecosystem services (due to their different ranges of values).

Dependency of Economic Sectors on BES

To assess the dependency of economic sectors on BES, we used the online tool "Exploring Natural Capital Opportunities, Risks and Exposure (ENCORE)"[91] developed by the Natural Capital Finance Alliance in partnership with UNEP-WCMC. The tool includes 167 economic sub-industries according to the Global Industry Classification Standard (GICS®[92]) and 21 ecosystem services they potentially depend on for their production processes. To determine which ecosystem services are more critical to a production process we considered the materiality ratings offered by ENCORE that assess how significant the loss of functionality in a production process is, if an ecosystem service were disrupted, and how significant the resulting financial loss is.[93] We converted the materiality ratings to a 1–5 scale, with 1 representing very low materiality (limited loss of functionality and financial impacts) and 5 representing very high materiality (severe loss of functionality and financial impacts).

From the 21 ecosystem services included in the ENCORE analysis we considered only the ecosystem services related to those included in the SRI BES Index. For that matter, we linked the ecosystem services included in the SRI BES Index to the ENCORE ones (as shown in Table A3-1) based on their definitions and, in some cases, performed further modifications to increase accuracy of the results. The Coastal Protection and Food Provision services of the SRI BES Index are not included in the ENCORE set of ecosystem services, and are thus excluded from the dependency on BES analysis.

Ecosystem services included in the SRI BES Index	Ecosystem services included in the ENCORE assessment	Nature's contribution to people according to IPBES
Habitat Intactness	Maintain nursery habitats	Habitat creation and maintenance
Pollination	Pollination	Pollination and dispersal of seeds
Air Quality & Local Climate[94]	Ventilation Climate regulation	Regulation of air quality Regulation of climate
Water Security[95]	Groundwater Surface water	Regulation of freshwater quantity, location and timing
Water Quality	Water quality	Regulation of freshwater and coastal water quality
Soil Fertility	Soil quality	Formation, protection and decontamination of soils
Erosion Control	Mass stabilization and erosion control	Regulation of hazards and extreme events
Coastal Protection	n/a	
Food Provision	n/a	Food and feed
Timber Provision	Fibres and other materials	Materials and assistance

Table A3-1: List of ecosystem services included in the SRI BES Index, their corresponding services included in the ENCORE assessment, and the IPBES classification. "n/a" indicates ecosystem services that are not defined.

[90] Carroll, M.L., DiMiceli, C.M., Wooten, M.R., Hubbard, A.B., Sohlberg, R.A., Townshend, J.R.G (2017). MOD44W MODIS/Terra Land Water Mask Derived from MODIS and SRTM L3 Global 250m SIN Grid V006 [Data set]. NASA EOSDIS Land Processes DAAC. https://doi.org/10.5067/MODIS/MOD44W.006

[91] Accessed via https://encore.naturalcapital.finance/en/

[92] The Global Industry Classification Standard (GICS®) was developed by and is the exclusive property of MSCI Inc. and Standard & Poor's

[93] Exploring Natural Capital Opportunities, Risks and Exposure: A practical guide for financial institutions, Natural Capital Finance Alliance and UN Environment World Conservation Monitoring Centre (Geneva, Oxford and Cambridge), 2018

[94] Dependency calculated as the average value of the materiality scores of two ENCORE ecosystem services to capture the contribution of ecosystems to the regulation of air quality and climate.

[95] Dependency calculated as the average value of the materiality scores of two ENCORE ecosystem services since the "Water Availability" indicator for the quantification of Water Security includes both water sources.

Next, the materiality scores for the dependency of each GICS® (Global Industry Classification Standard) production process on the individual ecosystem services were aggregated in their respective sub-industries using the average values for each ES. To calculate the dependency of each production process on all ecosystem services included in the SRI BES Index we use a weighted average including three criteria: the average materiality score, the maximum materiality score and the number of ecosystem services that the production process depends on.[96] To emphasize the importance of direct inputs from the natural environment to the economy, we assign double weights[97] to the dependency on Water Security and Timber Provision for the calculation of the average materiality score criterium. The aggregated dependency of each production process using these criteria is further aggregated at a sub-industry level using the average values.

For the incorporation of economic data in our dependency analysis we used economic indicators provided by Oxford Economics[98] that are based on the NACE Rev2 (Statistical Classification of Economic Activities in the European Community) industry classification.[99] Therefore, we converted the GICS® sub-industries of the ENCORE tool to the 4th hierarchical level of NACE (EU Technical Expert Group on Sustainable Finance 2019).[100] For NACE classes that are linked to more than one GICS® sub-industries, we selected the best fit. Following the conversion of the materiality scores to the NACE industries, we aggregate them from the 4th to the 1st (sectors) hierarchical level using the average value of the materiality score for the individual ecosystem services and the aggregated dependency on all services included in the SRI BES Index.

Following the consideration of different classifications of this dependency, we conclude that the most accurate is to classify the dependency values as "Low", "Moderate" and "High", using terciles, with the dependency of sectors belonging in the top tercile (values > 3.15) as "High" and in the bottom tercile as "Low" (values < 2.3).

From the economic indicators provided by Oxford Economics for different countries,[101] we select the "Value-added output, as % of GDP" for 2018, presenting the contribution of each economic sector to the GDP. For each economic sector and each country, we produced a weighted sum of the dependency of economic sectors on BES; the weights represented each sector's share to the country's GDP. The weighted dependency was classified to low, medium and high based on the terciles. It must be noted that certain NACE sectors were bundled in the datasets of Oxford Economics, thus, we followed the same listing for our results.

Finally, for the country profiles in Figure 12 we combine the share of fragile and intact ecosystems in the countries for which we have the weighted dependency deriving for the sectoral contribution to the national GDP. We also incorporate a societal dimension with population density data for 2018[102] consistent with the 2018 economic indicator for GDP used.

[96] The incorporation of three criteria follows the „Nature Risk Rising: Why the Crisis Engulfing Nature Matters for Business and the Economy", World Economic Forum in collaboration with PwC, January 2020
[97] In line with the UNEP FI suggestion presented in the „Setting targets to align finance with global policy goals for ecosystem resilience" webinar March 4 2020, accessed via https://www.unepfi.org/extranet/extranetresources/past-webinars/
[98] Source: Oxford Economics 2020 https://data.oxfordeconomics.com Accessed 09/02/2020
[99] EuroStat Methodologies and Working papers „NACE Rev.2 Statistical classification of economic activities in the European Community", Office for official Publications of the European Communities, 2008
[100] EU Technical Expert Group on Sustainable Finance 2019. Handbook of Climate Transition Benchmarks, Paris-aligned Benchmark and Benchmarks' ESG Disclosures, December 20th, 2019.
[101] This indicator is provided for a selection of countries.
[102] Food and Agriculture Organization and World Bank population estimates, accessed via http://www.data.worldbank.org 06/07/2020

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