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Marketing material

Earth Systems

Exploring the climate-biodiversity-land-water-oceans-just transition nexus

Michael Lewis,
Head of
Research ESG

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- The Earth systems underpin the well-being of our societies, but, worryingly six of the nine planetary boundaries are now breached[1]. It is essential, more than ever, that we move economic growth onto a more sustainable footing. This requires a framework for economic growth that is not detrimental to the stock of natural capital and helps to reduce societal inequalities
- In this report, we extend our investor agenda for ocean sustainaiblity[2] to the broader Earth systems' nexus of climate, biodiversity, land, water and oceans, with a specific focus on forests, land and agriculture
- Global leadership at December's COP15 biodiversity summit is required and it must be aligned to the COP climate summits. This may materialise since Climate COP27 and COP28's hosts Egypt and the United Arab Emirates have high food import requirements[3]
- It requires broadening the agenda from simply focusing on climate change and greenhouse gas emission reduction to addressing all of the planetary boundaries in unison given the interconnectivities between them
- Not only must bodiversity ambition include turning 30% of land and sea into protected areas, putting an end to deforestation and land degradation and reducing pesticide use by 50% but also avoiding food loss and waste, the wider adoption of sustainable agricultural practices, increasing company commitments to science-based nature targets, and the development of an Earth systems' taxonomy.
- Investor engagement with companies and policy-makers have a role to play to help advance these goals. We believe forests, land and agriculture also need to be at the heart of this agenda since the agricultural sector accounts for 70% of the world's total freshwater withdrawal[4], spurs up to 80% of deforestation[5], causes around 70% of the projected loss of terrestrial biodiversity[6] and is responsible for around 25% of greenhouse gas emissions[7]
- A coordinated approach across all Earth systems and involving multiple stakeholders may then begin to address the significant investment gap that exists since for those Sustainable Development Goals (SDGs) directly related to the biosphere, namely life below water (SDG14), life on land (SDG15), clean water and sanitation (SDG6) and climate action (SDG13), which are amongst the least funded[8]

[1] Stockholm Resilience Centre (April 2022). Freshwater boundary exceeds safe limits
[2] DWS Research Institute (October 2021). Oceans & climate- exploring the nexus
[3] World Bank (April 2022). A new global food crisis is building
[4] World Bank (October 2022). Water in agriculture https://www.worldbank.org/en/topic/water-in-agriculture
[5] Kissinger G., Herold M., De Sy V. (2012). Drivers of deforestation and forest degradation
[6] WWF (2021). Farming with biodiversity
[7] OurWorldInData (March 2021). How much of greenhouse gas emissions come from food?
[8] OECD: The SDG financing lab (latest data 2019)

1 / The cost of wealth

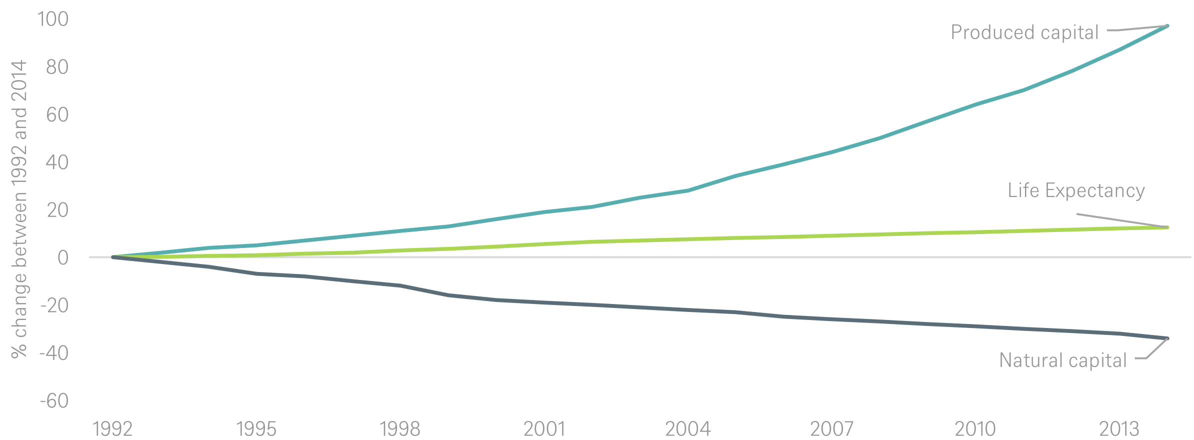
The Anthropocene epoch: human activities impact on the Earth's climate and environment

For the past 11,650 years, the earth's climatic environment has been relatively stable and supported the conditions for human societies to develop and thrive. However, this stability is now threatened as the planet transitions from the Holocene to the Anthropocene epoch whereby humans have become the dominant influence on the climate and the environment.

The onset of the industrial revolution marked the advent of the Anthropocene epoch such that over the past 100 years the world has enjoyed unprecedented prosperity in terms of wealth and living standards. For example, since the middle of the last century, economic output is up more than thirteen-fold in real terms, and human life expectancy has risen by 27 years globally[1]. However, these achievements have come at a cost. The stock of natural capital, such as forests, fisheries, agricultural land and minerals, have fallen by 40% on a per capita basis[9] since 1992, Figure 1.

Moving economic growth onto a more sustainable footing requires a framework for economic growth that is not detrimental to the stock of natural capital since, on current projections, demand for energy by 2050 will double while the demand for water and food is expected to increase by up to 30%[10]. In doing so, a more comprehensive approach to the climate crisis will emerge that addresses both restoring ecosystem services and nature's role in climate regulation.

Figure 1: Living standards have risen to the detriment of natural capital



Source: UK HM Treasury (February 2021). The economics of biodiversity: Dasgupta review

Planetary boundaries: The safe operating of the Earth's systems

Not surprisingly, the systemic risks posed by environmental factors have become an increasing focus for investors as illustrated by the World Economic Forum's annual Global Risks Reports. The findings show that over the past decade environmental risks have been displacing economic and financial factors as the greatest perceived threats to the financial system. The health of the planet - specifically climate change and biodiversity loss - are now viewed as among the main long-term threats to the world, with damaging impacts on people and societies.

[9] UK HM Treasury (February 2021). The economics of biodiversity: The Dasgupta review
[10] Nature (2019). Reassessing the projections of the World Water Development Report

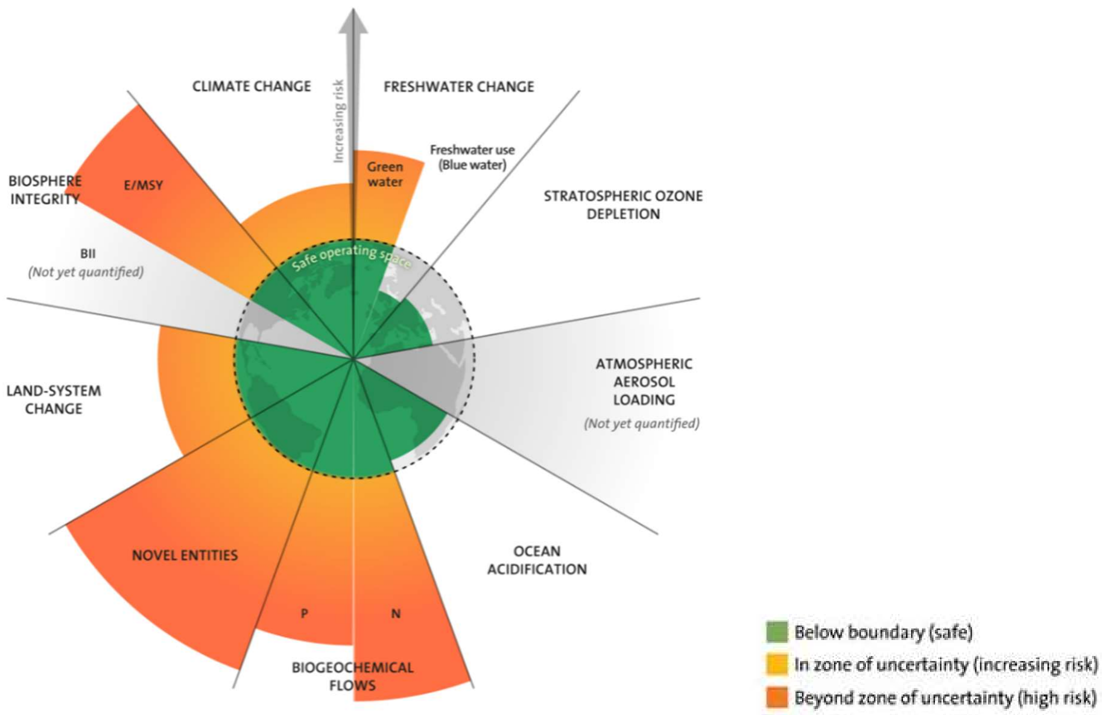
To help better understand these risks, in 2009 the Stockholm Resilience Centre[11] (SRC) first published their concept of planetary boundaries, Figure 2. Their work, which continues to be updated, identifies the nine processes or planetary boundaries which regulate the stability and resilience of the Earth's systems.

These processes can be clustered into four categories:

1. Global biogeochemical cycles of carbon, water, nitrogen and phosphorous
2. Major physical circulation systems of the planet, namely climate, oceans and stratosphere
3. Biophysical features of the Earth which support the self-regulatory capacity of the planet via marine and terrestrial biodiversity and land systems
4. And finally, aerosol loading and chemical pollution which are associated with anthropogenic global change

When these boundaries are crossed, and the Earth moves outside of its safe operating system, it increases the risk of generating large-scale abrupt or irreversible environmental changes.

Figure 2: Planetary boundaries pose systemic risks to the financial system



Source: Azote for Stockholm Resilience Centre, based on analysis in Persson et al 2022; J. Lokrantz/Azote based on Steffen et al. 2015. Planetary boundaries: Guiding human development on a changing planet (Updated April 2022).

According to their latest findings[12], the SRC's work shows that six of the nine planetary boundaries have already been breached. These are:

– Biosphere integrity which refers to biodiversity loss and extinctions. This is leading to what is termed the sixth mass extinction which has occurred over the past 4.5 billion years. However, this time it is being driven by humanity's demand for food, water, and natural resources rather than natural disasters such as volcanic eruptions

[11] Stockholm Resilience Centre, Stockholm University. The nine planetary boundaries https://www.stockholmresilience.org/research/planetary-boundaries/the-nine-planetary-boundaries.html
[12] Stockholm Resilience Centre (April 2022). Freshwater boundary exceeds safe limits

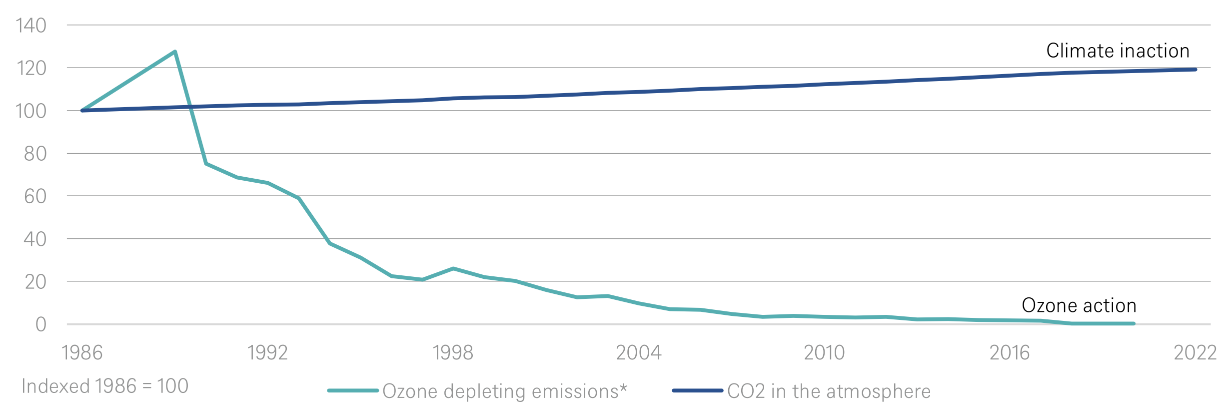
- Industrial and agricultural processes have led to biogeochemical flows of nitrogen and phosphorous and their polluting impacts on the land and seas
- Climate change and the concentration of CO_2 in the atmosphere has reached 420 parts per million, levels not seen in over 4.1 million years, a 30% rise since 1960, 50% higher than pre-industrial levels and with implications for global warming[13]
- Land-system change and the conversion of forests to other uses such as crops, grazing land, mining, roads, and human settlements, with impacts on water flows and biodiversity
- Novel entities relate to the emissions of toxic and long-lived substances such as synthetic organic pollutants, heavy metal compounds and radioactive materials with impacts on ecosystems such as marine mammals. There has been a 50-fold increase in the production of such chemicals since 1950 and this is projected to triple again by 2050[1]
- Green water (as opposed to blue water) refers to the deterioration in soil moisture due to climate change and deforestation

While its boundary has not yet been breached, ocean acidification caused primarily by CO_2 absorption, is moving towards its planetary boundary with knock on impacts on marine heatwaves, marine organisms and coral bleaching.

While the task ahead is certainly daunting, we can look to stratospheric ozone depletion for a glimmer of hope. In the 1970s, scientific research showed how ozone depleting substances (ODS), found in air conditioning units, refrigerators and aerosols, were leading to a growing hole in the ozone layer over Antarctica. At its peak in September 2000, the ozone hole extended over 28 million square kilometers, an area equivalent to almost seven times the territory of the European Union[14].

To address these risks, in 1989 the Montreal Protocol came into force. The agreement was the first UN Treaty to be ratified by all 198 UN Member States with the ambition of reducing the production and consumption of nearly 100 ODS. Within 30 years, 99% of ODS have been phased out and contributed to a general closing in the ozone hole which is expected to be largely repaired by 2060[15]. According to another study[16] published last year, this action may have prevented 443 million cases of skin cancer and 63 million incidents of vision damage. Ultraviolet light damage to plants has also been reduced so that more carbon is stored in nature, preventing the world from being 0.5-1.0°C warmer, and potentially delaying many climate impacts[17]. In contrast, the trajectory of greenhouse gas emissions displays a very different picture, Figure 3.

Figure 3: The differing pathways of CO_2 versus ozone depleting emissions



* Global consumption of ozone-depleting substances (ODS)
Source: European Environment Agency (EEA), National Oceanic and Atmospheric Administration (NOAA), DWS Investment GmbH (November 2022)

[13] NOAA (June 2022). Carbon dioxide now more than 50% higher than pre-industrial levels
[14] European Environment Agency (December 2021). What is the current state of the ozone layer?
[15] NOAA (2-18). Scientific assessment of ozone depletion
[16] Scientific American (October 2021). Landmark ozone treaty could prevent more than 400 million cases of cancer
[17] UNEP (September 2021). Rebuilding the ozone layer: how the world came together for the ultimate repair job

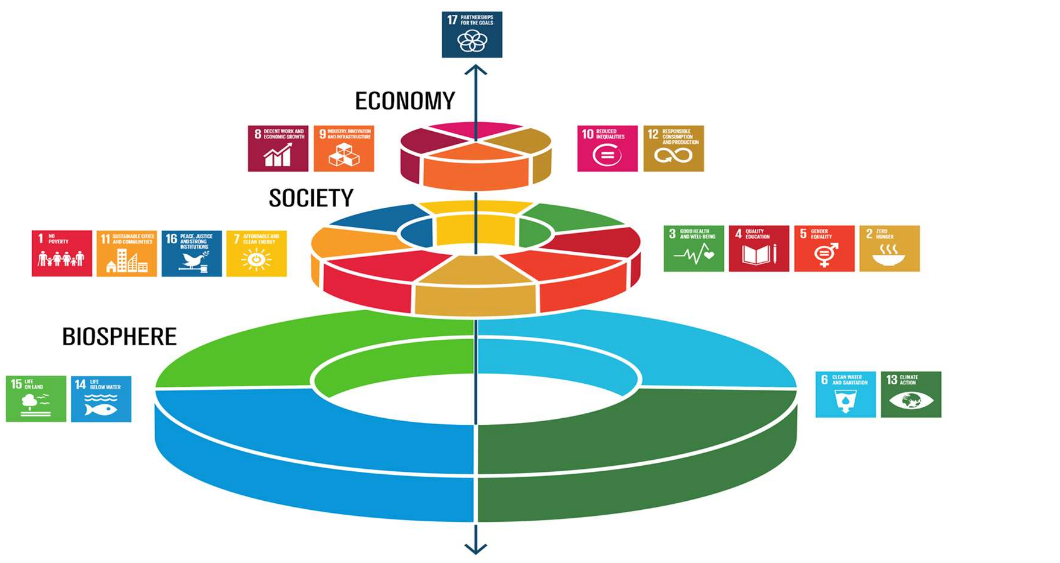
2 / The Earth systems' nexus

This section explores how the planetary boundaries are connected, the factors driving their pathways, the countries and regions most affected, and our recommendations for an Earth Systems agenda that helps plug the biosphere investment gap. While investors often look at planetary boundaries in isolation, such as climate change, one needs to consider them holistically to ensure that investment capital is allocated sustainably.

Exploring the climate-biodiversity-land-water-oceans nexus

Nature, or ecosystem services, confers significant benefits to humans, from the provision of food, fuel and fibre, to the purification of air and water and the discovery of new medicines. Ecosystems can therefore be described as 'environmental assets' that, like other capital assets, provide a flow of services over time. According to one estimate[18], at a global level nature provides services worth at least US$125 trillion per annum. When it comes to examining the Earth systems through an investment lens, the SRC clusters the Sustainable Development Goals under three categories, namely the biosphere, society and the economy. Not only does this recognize the interconnectivity between the three, it also how the biosphere lies at the foundation of achieving all societal and economic goals, Figure 4.

Figure 4: The sustainable development goals pyramid



Source: Azote Images for Stockholm Resilience Centre

But the ability of achieving the Sustainable Developments Goals by 2030 is undermined by attacks on the biosphere. Whether it be life on the ground, in the air or in the water, human activity is primarily responsible for many of the planetary boundaries being crossed. Given their interconnectivity, crossing one boundary can also alter the pattern of other planetary boundaries. We label this the Earth Systems' nexus and specifically the linkages between our climate, biodiversity, land, water and oceans.

Three of the most important threats to the biosphere's decline[19] are:

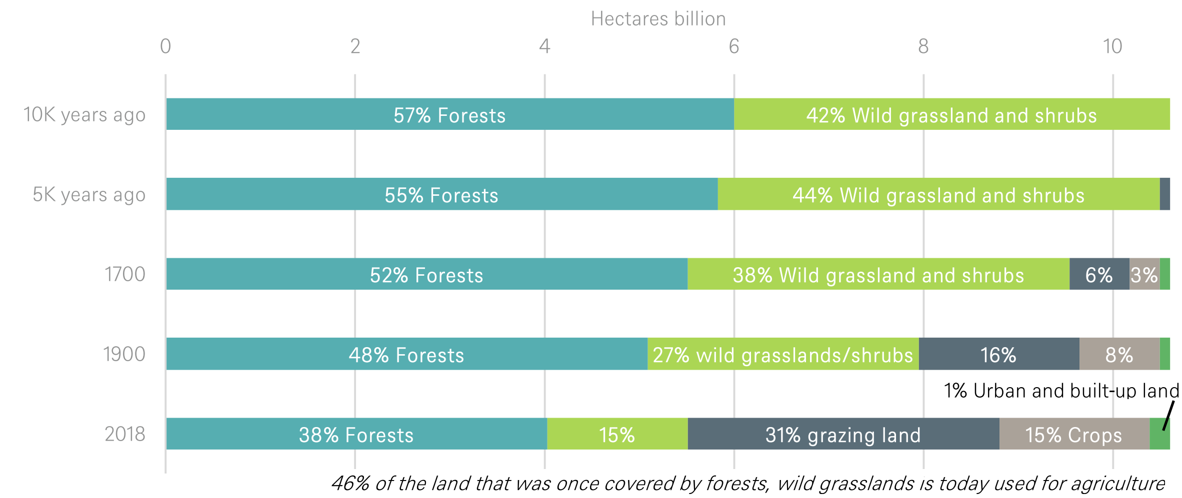
- Land use change
- Climate change
- Pollution

[18] WWF (2018). Living planet Report 2018
[19] Other threats include the overexploitation of animals alongside invasive species

Threat #1: Land use change

Land use change can lead to the continuous decline of key ecological functions such as the carbon sequestration capacity of forests which increases the threat of another planetary boundary: climate change. The primary driver of land use change is the expansion of agricultural land at the expense of forests and grasslands. Latest figures show that 46% of the land that was once covered by forests and grasslands, or 4.8 billion hectares, is split between grazing land (67%) and the cultivation of crops (33%). In addition to land use change for cultivation, agriculture also accounts for 70% of the world's total freshwater withdrawal[20] and up to 80% of deforestation[21]. It also causes around 70% of the projected loss of terrestrial biodiversity[22] and is responsible for between 25-30% of greenhouse gas emissions[23]. It is therefore easy to see how food systems play a central role in Earth system (in)stability.

Figure 5: Agriculture has been the primary cause of land use change and specifically deforestation



Source: DWS Research Institute, OurWorldinData, Historical data on forests from Williams (2003) – Deforesting the Earth. Historical data on agriculture from The History Database of Global Environment (HYDE). Modern data from the FAO

Forests cover 38% of the world's land area, amounting to 4.06 billion hectares[24]. The conversion of forests and woodlands for crops, grazing land, mining, roads and human settlements is responsible for 12% of global greenhouse gas emissions, more than the global transportation sector[25]. The worldwide loss in forest cover between 2004 and 2017 is estimated at more than 43 million hectares, an area roughly equivalent to the size of Morocco[26]. Put another way, up to 15 billion trees are being cut down every year across the world[27] . Forests also are an integral component of the water cycle as they are the source of 75% of the world's freshwater. In addition, forests are home to half of the world's land-based species and more than a billion people live in or around forests, of which many include indigenous communities. The role of forests is therefore changing when it comes to regulating the Earth's climate. Forests work as carbon sinks through photosynthesis and the storage of carbon in leaves and the soil. Their storage ability and efficiency varies according to the availability of light, heat and water so there is seasonality in the rates of carbon sequestration, with higher rates in the growing season. According to a recent

[20] World Bank (October 2022). Water in agriculture https://www.worldbank.org/en/topic/water-in-agriculture
[21] Kissinger G., Herold M., De Sy V. (2012). Drivers of deforestation and forest degradation. A 2022 study shows that agriculture is responsible for 90% of tropical deforestation
[22] WWF (2021). Farming with biodiversity
[23] Our world in data How much of global greenhouse gas emissions come from food? - Our World in Data
[24] FAO (2020). The state of the world's forests 2020
[25] European Commission. Combatting tropical deforestation: the REDD+ initiative
[26] WWF (2021). Deforestation Fronts: Drivers and responses in a changing world
[27] WWF The effects of deforestation The Effects of Deforestation | WWF

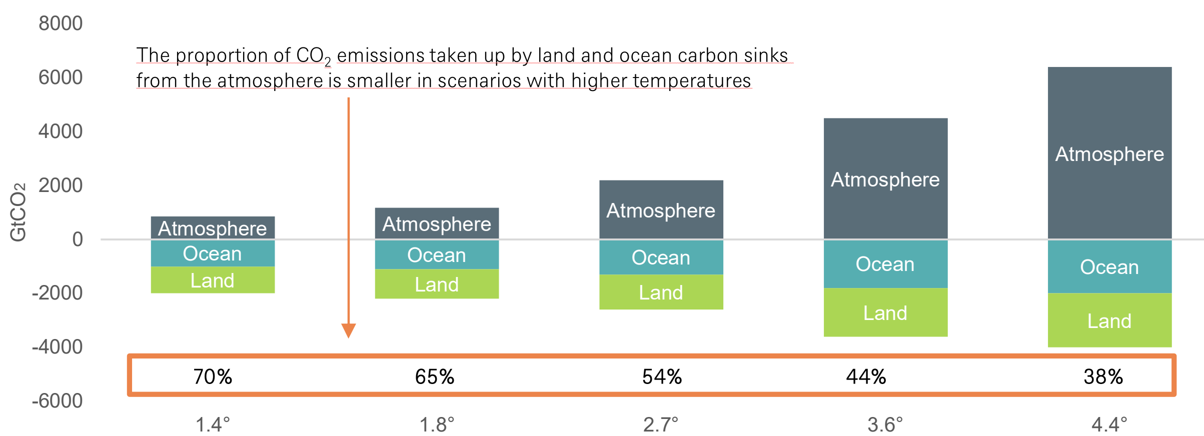
study, the Earth's forests sequestered about twice as much CO_2 as they emitted between 2001 and 2019 absorbing a net 7.6 billion tonnes of CO_2 per annum, or one and a half times more carbon than the United States emits annually[28].

Regionally, the majority of forested area is concentrated in just a handful of locations with Brazil, Canada, China, the Russian Federation and the United States home to over a half of the world's forests. In terms of zones, forests occur across tropical, subtropical, boreal and temperate areas although tropical and subtropical ecosystems are estimated to account for up to 70% of all the carbon sequestered by the Earth's forests[29].

The most important of these rainforests are in the Amazon, Congo River basin and Southeast Asia, but each of these is being undermined by deforestation, fires and droughts. According to the WWF[30], the majority of deforestation is occurring in 24 areas across South America, sub-Saharan Africa (SSA), Southeast Asia and Oceania. These developments are therefore altering the role of forests as carbon sinks, with spill-over effects onto the climate change planetary boundary. For example, a report[31] last year revealed that south-eastern part of the Amazon has become a source of carbon emissions, reversing its historical trend. At an aggregate level, the effectiveness of land and ocean carbon sinks declines as the global temperature increases. Scenarios of cumulative sinks from 1850 to 2100 are presented in Figure 6.

During the period 1850 to 2019, the observed land and ocean sinks absorbed 1,430 $GtCO_2$ or 59% of carbon emissions. On current trends, it is estimated[32] that the planet is set to warm by approximately 2.7ºC by the end of the century. This would imply our oceans and land ecosystems will be able to absorb little more than 50% of CO_2 emissions compared to 70% in a 1.4ºC world. Note that land and oceans are not substantial sinks for other greenhouse gas emissions, hence we focus on carbon dioxide exclusively. For more details, please refer to our 2021 research paper[33] which outlined an investor agenda to drive ocean sustainability.

Figure 6: Land and oceans continue to play an essential but declining role under different climate scenarios



Sources: DWS Research Institute, IPCC Assessment Report 6 (AS6) dated August 2021. The chart shows cumulative CO_2 emissions taken up by land and oceans and remaining in the atmosphere (grey) under the five illustrative scenarios from 1850 to 2100.

[28] Nature (January 2021). Global maps of twenty-first century forest carbon fluxes
[29] Nature (April 2021). Mature Andean forest as globally important carbon sinks and future carbon refuges
[30] WWF (2021). Deforestation Fronts: Drivers and responses in a changing world
[31] Nature (July 2021). Amazonia as a carbon source linked to deforestation and climate change
[32] Climate Action Trackers (November 2021). Current policies and action scenario
[33] DWS Research Institute (November 2021). Oceans & Climate: Exploring the nexus

Threat #2: Climate change

The climate change planetary boundary identifies 350 parts per million (ppm) of CO_2 concentrations in the atmosphere as the level below which the Earth operates within safe limits[34]. This level was broken in 1988[35]. It is estimated that to ensure a 50% chance of stabilizing average global temperatures at 2°C above pre-industrial levels, CO_2 concentration in the atmosphere must not exceed 450 ppm[36]. The latest estimates[37] indicate that carbon dioxide in the atmosphere hit a new high of 421 ppm this year. These trends are not only driving the increasing frequency and intensity of extreme weather events, but also leading to contagion effects on many of the other planetary boundaries.

Climate change and the effect on oceans

With more CO_2 in the atmosphere, the chemical composition of oceans is changing, becoming warmer and more acidic. This process of acidification is then affecting marine organisms, by inhibiting the growth of shells and skeletons, and causing coral bleaching. This holds specific dangers since when it comes to oceans, they hold 80% of the world's biodiversity[38], and provide 50% of our oxygen[39]. 90% of all international trade is transported via the sea[40] and 3 billion people are dependent on the ocean economy for their livelihoods[41].

Rising ocean temperatures are also increasing the frequency, intensity and duration of marine heatwaves that can damage coastal habitats. These are important blue assets given their carbon storage properties in addition to their ability to protect coastal communities from sea level rise and storm surges.

Since the industrial revolution, oceans and their coastal habitats have been responsible for absorbing approximately one third of the CO_2 emitted by humans[42]. However, the ability of our oceans to absorb CO_2 is weakening due to temperature rise and acidification, and marine biodiversity losses are mounting as result of increasing chemical pollution, plastic debris, marine traffic, overfishing and the discharge of pollutants and pesticides in agriculture. Combined, these trends are increasing the likelihood that the next planetary boundary to be crossed will be ocean acidification.

Climate change is also driving the rapid increase in sea level rise. According to the Intergovernmental Panel on Climate Change (IPCC), sea levels rose by 20cm between 1901 and 2018, yet a similar rise is now projected to occur in the next 30 years alone even if we take more remedial action today[43]. In terms of attribution, over the 1971-2018 period, the thermal expansion of warm ocean waters was responsible for 50% of sea level rise, while ice loss from glaciers contributed 22%, ice sheets 20% and changes in land water storage 8%. More recently, ice sheet and glacier loss have become the dominant contributors to global mean sea level rise[44].

Climate change and the effect on forests

Rising global temperatures are also increasing the incidence of fires and droughts and threatening forests globally. Whether man-made or triggered by droughts, forest fires are not just weakening the carbon sink capacity of forests, but alongside deforestation and broader climate change trends are leading to a deterioration in terrestrial precipitation, evaporation and soil moisture, so-called green water[45]. Forest fires are also having dangerous impacts on biodiversity and specifically species mortality. For example, in the 2019-20 Australian bush fires it is estimated that 143 million mammals, 2.46 billion reptiles, 180 million birds and 51 million frogs were killed or displaced over an impacted area of 19 million hectares, an area slightly larger than Syria.

[34] Ecology & Society (2009). Planetary boundaries: Exploring the safe operating space for humanity
[35] OurWorldInData (November 2022). Global atmospheric CO2 concentration
[36] IPCC Sixth Assessment Report (September 2021)
[37] NOAA (June 2022). Carbon dioxide now more than 50% higher than pre-industrial levels
[38] National Geographic https://media.nationalgeographic.org/assets/file/one-ocean-chapter-3.pdf
[39] The EU blue economy report 2021 https://op.europa.eu/en/publication-detail/-/publication/0b0c5bfd-c737-11eb-a925-01aa75ed71a1
[40] International Chamber of Shipping (data as of September 2020)
[41] OECD (data as of 2020); world population data from Statista
[42] Biogeosciences Khatiwala S. et al (April 2013). Global ocean storage of anthropogenic carbon
[43] IPCC Assessment Report 6 (AS6) (August 2021)
[44] IPCC Assessment Report 6 (AS6) (August 2021). Data covering the period 2006 to 2018
[45] Potsdam Institute for Climate Impact Research (April 2022). Planetary boundaries update: freshwater boundary exceeds safe limits

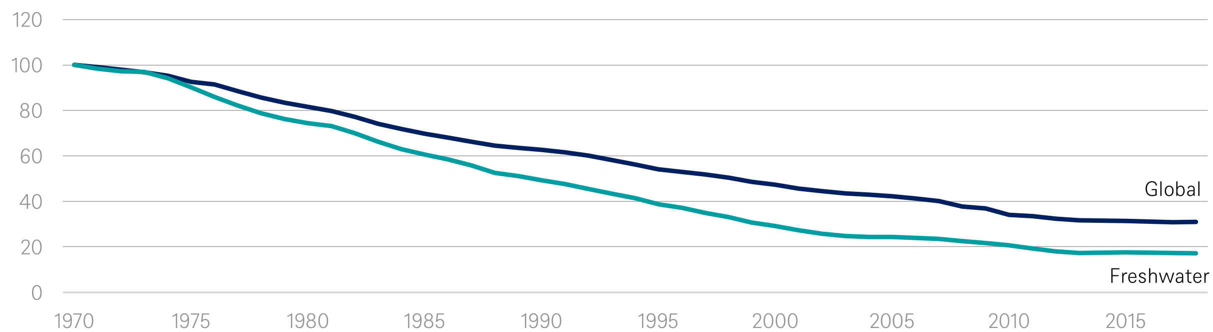
Climate change and the effect on species populations

The Australian bushfires illustrate the significant impact these events can have on species populations and biodiversity. What is now termed the sixth mass extinction, is being caused by human activity, unlike previous extinctions over the past 4.5 million years, which were caused by natural phenomena such as volcanic eruptions. Estimates suggest that the pace of extinction rates is now running 100 or more times faster than historical extinctions.

Threat #3: Pollution

It is estimated that 80% of the world's wastewater is returned to the environment untreated and this is a source of methane, which has approximately 84 times more warming potential[46] than CO_2. 50% of US rivers and 60% of European surface water are polluted while a third of the rivers in Asia, Africa and Latin America are severely polluted by pathogens[47]. This pollution impacts species decline, as freshwater species populations have dropped by 83% since 1970, compared to a 69% fall across all species[48]. Figure 7.

Figure 7: Population trends of vertebrate species in global and freshwater habitats*



Source: WWF Living Planet Report 2022. In its latest report the WWF no longer publishes population trends for marine and terrestrial vertebrates. In previous reporting decline rates in these categories were lower than compared to global and freshwater species (Indexed 1970 =100)

The agricultural sector is one of the major contributors to water pollution globally. This pollution comes in the form of fertilizers and pesticides for crops (nitrates and phosphates) as well as veterinary medicines such as hormones and antibiotics for livestock. Nitrate pollution diminishes the carbon sequestration capacity of coastal habitats such as salt marshes. Globally around 115 million tonnes of mineral nitrogen fertilizers are applied to croplands each year. A fifth of these nitrogen inputs accumulate in soils and biomass, while 35% enter the oceans[49].

The resulting contamination in rivers, lakes and ultimately oceans is not only a threat to human health, but also causes eutrophication, the build-up of algae blooms that starve aquatic water systems of light and oxygen, creating so-called dead zones. In the past 50 years, the number of ocean areas where oxygen levels are too low to support marine life have increased fourfold such that today, there are over 400 oceanic dead zones worldwide, primarily concentrated in Europe, eastern and southern US, and Southeast Asia.

[46] Each greenhouse gas has a different global warming potential (GWP) and persists for a different length of time in the atmosphere. The three main GHG and their 20-year GWP are carbon dioxide, methane and nitrous oxide
[47] CDP (April 2020). Cleaning up their act
[48] WWF (October 2022). Living Planet Report 2022
[49] FAO (April 2018). More people, more food, worse water? A global review of water pollution from agriculture

3 / The hotspots

The three major threats to the Earth Systems highlighted in the previous section – land use change, climate change and pollution – are leaving their geographical imprint in terms of:

- Water stress
- Deforestation
- Biodiversity loss

In this section, we examine these imprints by geographic location. Not surprisingly, given the linkages between the planetary boundaries, the factors driving the Earth to move outside its safe operating system often have cascading effects. For example, deforestation often leads to biodiversity collapse and can in turn contribute to lower precipitation, which results in lower availability of fresh water, leading to water stress. We examine these factors in turn and illustrate the need for urgent and coordinated action when it comes to tackling the major threats to the Earth Systems.

Imprint #1: Water stress

Water use has increased sixfold over the past 100 years and will continue to rise given rising population levels, increased food production needs and increased urbanization. This water demand is usually categorized in three broad buckets – agricultural, industrial and domestic. By 2050, 51% of the world's population, 46% of global GDP and 40% of global grain production are forecast to be in areas facing high water risk[50]. To get a sense of the water stress across regions, we examine the ratio of freshwater withdrawals vis-à-vis renewable freshwater resources. A higher value provides an indication of the region's total withdrawal being close to its water basin's renewable resources. As can be seen in Figure 8, the regional water stress is highest in the Middle East and Central Asia.

Amongst the G7 countries, although the median value is relatively low at 2.3 (indicating medium stress) for all sectors, it is worth noting that this disguises country and regional disparities with Italy reporting the highest value (3.6 – High stress), followed by United States (3.2 – High stress). This is largely attributable to demands from the agricultural sector in both the countries. At a more granular level, the readings are even more extreme with areas like Sicily and California on par with the Middle East's "extremely high" water stress levels.

Figure 8: Water stress across regions (median regional readings)

Regional cluster	All Sectors	Industrial	Domestic	Agriculture
Advanced economies	2.0	2.0	2.0	1.9
Emerging and developing Asia	1.6	1.5	1.4	1.8
Emerging and developing Europe	1.7	1.7	1.6	2.1
Latin America and the Caribbean	0.8	0.7	0.7	0.9
Major advanced economies (G7)	2.3	2.2	2.2	2.9
Middle East and Central Asia	4.4	4.4	4.4	4.4
Sub-Saharan Africa	0.2	0.1	0.2	0.1
Others	2.0	1.8	1.8	2.1

Source: WRI Aqueduct Water Stress Projections, 2030 BAU Scenario, Water stress measures total annual water withdrawals (municipal, industrial, and agricultural) expressed as a percentage of the total annual available blue water. Higher values indicate more competition among users. The score is based on the ratio "Withdrawals/Available Flow" and the score between 0-1 indicates low stress (<10% reading for the ratio), between 1-2 indicates Medium stress (10-20%), between 2-3 indicates Medium to High stress (20-40%), between 3-4 indicates High stress (40-80%) and 4-5 indicates Extremely High stress (>80%)

[50] WWF Water Risk Filter, World Water Development Report 2021

Imprint #2: Deforestation

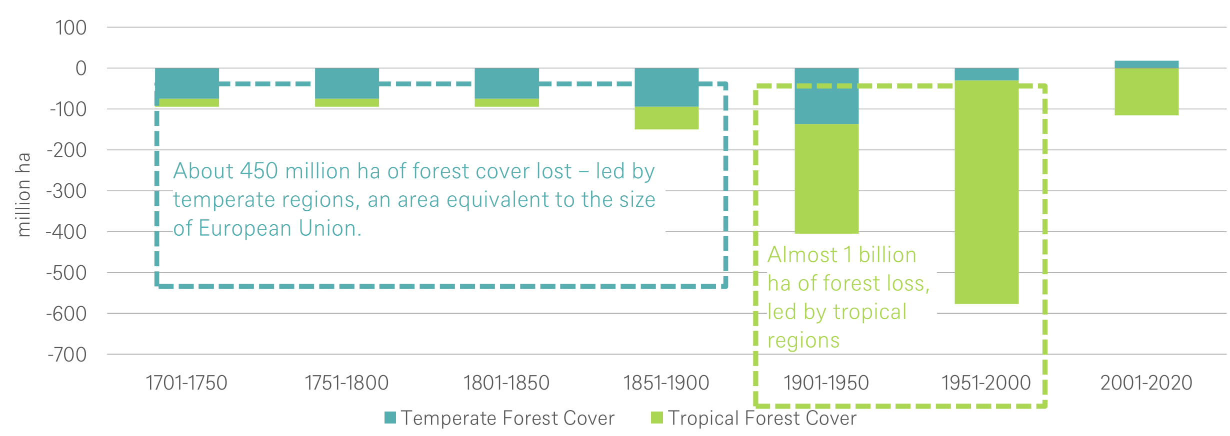
The world has lost around 1.5 billion hectares of forest since 1700, an area equal to one-and-a-half times the size of the United States[51]. From a regional perspective we split these net losses according to temperate and tropical forest cover, Figure 9. The temperate regions cover North America, Europe, Oceania, Russia and part of South Asia. On the other hand, the tropical regions encompass Latin America, Africa, and South-east Asia (including the Indian subcontinent) which are also more valuable from a carbon sequestration perspective[52].

From 1700 to 1900, about 450 million hectares of forest land was lost, primarily driven by losses in the temperate regions. This was attributable to population growth across Europe and North America and the associated requirement for more and more resources such as land for agriculture and wood for energy and construction purposes[53]. Heading into the 20th century, there was an even greater increase in the demand for agricultural land and energy from wood, triggering an acceleration in deforestation rates.

Between 1901 and 2000, the Earth lost a further one billion hectares of forest cover globally, more than two times the loss in the previous two centuries combined. The accelerated loss in forest cover over this time was mostly driven by tropical deforestation as countries across Asia and Latin America followed the path of Europe and North America. While global deforestation rates peaked in the 1980s and have since showed signs of a decline, forest loss in the tropical region has had a more pronounced negative impact on global biodiversity. This is because tropical forests are home to some of the richest and most diverse ecosystems on the planet, with over half of the world's species residing in tropical forests[54].

When it comes to endemic species, that is those species which only naturally occur in a single country, the picture is the same: subtropical countries are more abundant with unique wildlife. Tropical habitat loss is therefore the leading driver of global biodiversity loss and deforestation is the primary cause[55].

Figure 9: Forest cover loss between 1701 and 2020



Source: OurWorldinData, pre-1990 data from Williams (2006) – Deforesting the Earth. Post 1990 data from UN FAO Global Forest Resources Assessment (2020)

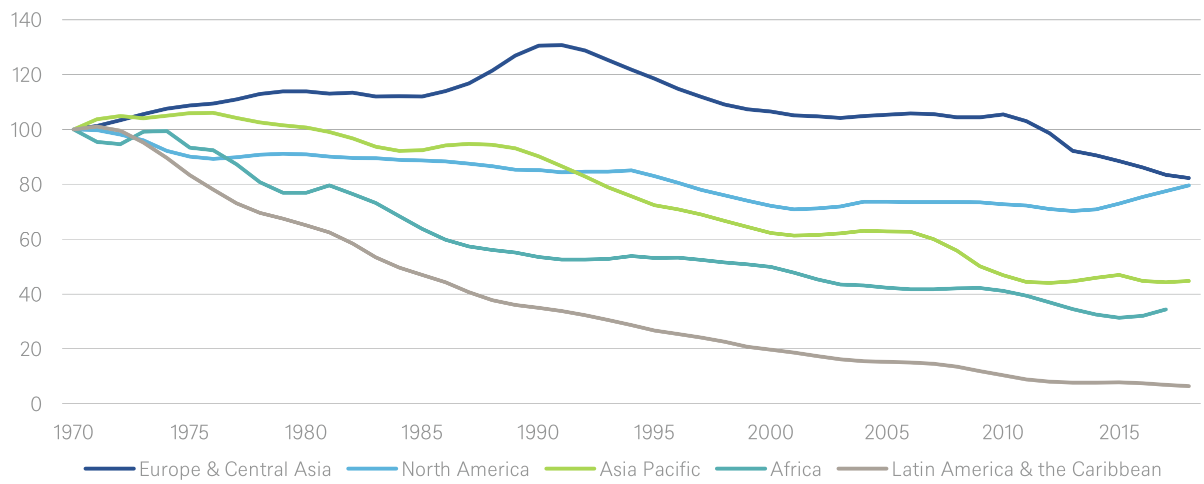
[51] OurWorldInData (November 2022). Deforestation and forest loss
[52] Tropical and subtropical ecosystems are estimated to account for up to 70% of all the carbon sequestered by the Earth's forests – see footnote 19
[53] Mather, A. S., Fairbairn, J., & Needle, C. L. (1999). The course and drivers of the forest transition: the case of France. Journal of Rural Studies, 15(1), 65-90. Mather, A. S., & Needle, C. L. (2000). The relationships of population and forest trends. Geographical Journal, 166(1), 2-13.
[54] Scheffers, B. R., Joppa, L. N., Pimm, S. L., & Laurance, W. F. (2012). What we know and don't know about Earth's missing biodiversity. Trends in Ecology & Evolution, 27(9), 501-510.
[55] Maxwell, S. L., Fuller, R. A., Brooks, T. M., & Watson, J. E. (2016). Biodiversity: The ravages of guns, nets and bulldozers. Nature 536(7615), 143

Imprint #3: Biodiversity loss

"How many species do we share our planet with?". This is hard to answer with precision. Most estimates put the number between 5 to 10 million[56]. Of these, the IUCN Red List tracks approximately 2 million of described species and updates this figure annually. To get a regional understanding of biodiversity loss, we rely upon WWF's Living Planet Index (LPI). The LPI was developed in 1997 to get a grasp on environmental change, with the primary aim of measuring the changing state of the world's biodiversity over time. To do so, the LPI uses wildlife population data from multiple years to calculate average rates of change in a large number of species across terrestrial, freshwater and marine systems. It tracks a total of 31,821 populations of 5,230 vertebrate species from around the globe since 1970 and consequently captures only a sub-sample of all species populations.

With that caveat in place, Figure 10 tracks species populations of mammals, birds, reptiles and amphibians by region. It reveals that species populations in tropical regions namely Latin America and the Caribbean, Africa, and the Asia Pacific are disproportionately affected compared to Europe and North America. This trend reflects tropical regions most exposed to intense deforestation. Species in these regions are often highly specialized and unable to adapt to changes in local conditions. On the other hand, temperate regions appear to have fared better, courtesy of the efforts targeted towards conservation, afforestation and restoration of wild ecosystems.

Figure 10: Living Planet Index by region



Source: WWF (2022). Living Planet Index database, only vertebrate species are included, within the following taxonomic groups – Birds, Mammals, Fish, Amphibians and Reptiles.

[56] Mora, C., Tittensor, D. P., Adl, S., Simpson, A. G., & Worm, B. (2011). How many species are there on Earth and in the ocean?. PLoS Biol, 9(8), e1001127. Costello, M. J., May, R. M., & Stork, N. E. (2013). Can we name Earth's species before they go extinct?. Science, 339(6118), 413-416. Scheffers, B. R., Joppa, L. N., Pimm, S. L., & Laurance, W. F. (2012). What we know and don't know about Earth's missing biodiversity. Trends in ecology & evolution, 27(9), 501-510.

4 / The Earth systems' investment gap

Financing in support of the Sustainable Developments Goals

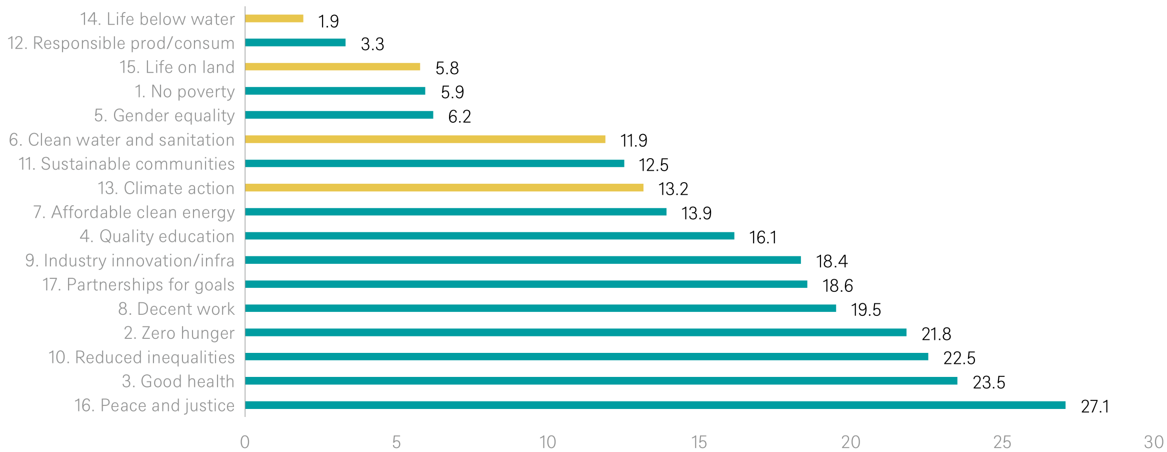
The Business and Sustainable Development Commission (BSDC) estimates that the Sustainable Development Goals (SDG) could be a key driver of economic growth and unlock opportunities worth up to US$12 trillion per annum by 2030, or more than a tenth of global output. In addition, the BSDC estimate that almost 400 million jobs could be created across the food and agriculture, cities, energy and materials and health and well-being sectors[57].

While financing towards the SDGs needs to increase, this rise needs to be disproportionately larger for the SDGs aligned to the Earth systems given their importance. According to the Organisation for Economic Co-operation and Development (OECD)[58], the SDG financing gap for developing countries is estimated to have totaled US$3.7 trillion in 2020, having been inflated by additional spending needs to address the covid pandemic and following a drop in external private financing. SDG financial flows can come in many forms across the public and private sectors as well as from domestic and external sources. These include official development assistance as well as private or blended SDG financing vehicles. However, we note that screening tools to identify publicly listed equities that may be aligned to SDG goals is unlikely to close the investment gap as such capital is already deployed. The most effective action is likely to come from new forms of capital deployment.

One route to assess capital allocation to the SDGs, and specifically investment flows to the biosphere, is through the OECD's SDG financing tracker. This tracker pools bilateral and multilateral aid, or so-called official development assistance, and private providers (philanthropies) who report to the OECD. When it comes to financing the Earth Systems their latest figures provide grim reading. It shows financial flows to the four SDGs directly related to the biosphere, namely life below water (SDG14), life on land (SDG15), clean water and sanitation (SDG6) and climate action (SDG13), are among the least funded of the SDGs, Figure 11.

In fact, these four SDGs combined captured just 13.5% of all SDG funding from development finance with the ocean economy the most underfunded. UINCTAD data reveal a similar picture with international investment in food and agriculture declining 35% compared to pre-pandemic levels[59]. These illustrate why sizeable private sector resources will be required to complement official development assistance, and why investment flows need to be targeted to the appropriate biosphere and specifically in the geography where it is required.

Figure 11: Development finance by relevant sustainable development goal (US$ billion)



Source: OECD: The SDG financing lab. Data capture top 25 providers of overseas development assistance in 2019

[57] Business and Sustainable Development Commission (January 2017). Better business, better world
[58] OECD (February 2021). Closing the SDG financing gap in the COVID-19 era
[59] UNCTAD (June 2022). World investment report 2022 (percentage figure relates to number of projects)

Forecasts are based on assumptions, estimates, views and hypothetical models or analyses, which might prove inaccurate or incorrect

5 / The investor action agenda

An investor agenda that supports the climate-biodiversity-land-water-oceans-just transition nexus

Over the past few years key stakeholders have ramped up their efforts to protect and restore our natural environment. At a government level, this is illustrated by the Leaders Pledge for Nature signed in September 2020, which commits 94 heads of state and government, representing 38% of world GDP, to reverse biodiversity loss by 2030[60]. At a financial and corporate level, action includes the Finance for Biodiversity Pledge and the Business for Nature initiative respectively.

However, these efforts still fall short when compared to climate. For example, country commitments to net zero capture close to 90% of world GDP[61]. When it comes to companies, more than 60% of the S&P500's constituents have committed to net zero[62], compared to less than 20% pledging to protect biodiversity and natural capital[63]. In terms of disclosures, CDP data shows that more than 18,600 companies disclosed climate change data this year. The equivalent figures for forests and water security disclosure were roughly 1,000 and 4,000 companies, respectively[64]. Action is likely to be less effective if it fails to recognize the interconnection between the Earth systems,.

In this section, we focus on potential action in the food, land and agricultural sectors given the important role these processes play in the carbon, water, nitrogen and phosphorous cycles as well as their impacts on land use and terrestrial biodiversity[65]. We identify on a number of key areas:

- Reducing food loss and waste
- Promoting sustainable agricultural practices
- Increasing company commitments to science-based nature targets and deforestation
- Enhancing investor engagement and public advocacy to natural capital
- Supporting the role of indigenous communities and the Just Transition
- Promoting an Earth Systems' taxonomy

1. Reducing food loss and waste

For some time now food production has been able to support 1.5 times the world's current population[66]. However, 40% of the food grown around the world is either lost or wasted[67], at a time when 2.3 billion people were moderately or severely food insecure last year[68].

Food loss refers to losses that take place at the production, post-harvest and processing stages and are most prevalent in Central and Southern Asia due to factors such as poor refrigeration or rodents. In India, for example, about 10% of total food grains produced are lost post-harvest to such things as rodents that either consume or contaminate. However, helping to reduce food loss is an investment opportunity. For instance, thematic funds could make loans to help improve crop storage and market knowledge of food loss.

Food waste, on the other hand, relates to retailers' and consumers' behavior such as throwing away uneaten prepared food or food past its sell-by date. The consumer-goods industry has embraced the goal of reducing food waste. Ten of the largest

[60] Leaders' Pledge for Nature (January 2022). 2021: Summary of progress one year on
[61] Climate Action Tracker (September 2022). CAT net zero target evaluations
[62] S&P Global (October 2022). S&P500 net zero Paris-aligned ESG index S&P 500 Net Zero 2050 Paris-Aligned ESG Index | S&P Dow Jones Indices (spglobal.com)
[63] S&P Global (February 2022). Nature is climbing the agenda, but corporate biodiversity commitments remain rare
[64] Business For Nature (October 2022). More than 330 businesses call on Heads of State to make nature assessment and disclosure mandatory at COP15
[65] For more details on an investor agenda to drive ocean sustainability, please see our October 2021 report[65] "Oceans &Y Climate: Exploring the nexus
[66] Journal of Sustainable Agriculture (36: 595-598, 2012). We already grow enough food for 10 billion people, and still can't end hunger
[67] WWF (August 19, 2021). We're losing 40% of the food we produce. Here's how to stop food waste
[68] WHO (July 2022). Global hunger numbers rose to as many as 828 million in 2021

food companies set a goal to work with their 20 largest suppliers to cut food waste by 50% by 2030 – the 10x20x30 initiative[69]. In addition, analysis[70] across 700 companies found that every U.S. dollar invested in reducing food waste - from initiatives like staff training, food storage and handling improvements - returned 14 U.S. dollars. Many restaurants and hotel kitchens are even using Artificial Intelligence to cut waste, save money and deliver a strong return.

2. Promoting sustainable agricultural practices

The world needs to produce enough food, on less land and with fewer emissions. The Netherlands is the world's second largest exporter of agricultural products by value, despite being 270 times smaller than the United States, the world's largest agricultural product exporter. The efficiency of production means that the Netherlands has one of the highest crop yields, with a low environmental impact. For instance, the Netherlands produces more than 144,000 tons of tomatoes per square mile, many times larger than any other country[71]. The total water footprint of the Netherlands tomato production is 1.1 gallons per pound compared to a global average of 24.6.

Solutions include recycling wastewater, rainwater harvesting, drip irrigation technology, precision planting and hybrid seeds, improved infrastructure and pipes, and the introduction of desalination facilities. For example. with greenhouses covering 36 square miles (Manhattan is 23 square miles), the Netherlands is a powerhouse of precision, high yield, low impact food production[72]. From 2014, vegetable production increased 28% while energy use dropped 6%, pesticides dropped 9% and fertilizer dropped 29%. Spreading the adoption of the Netherlands' (and other countries') greenhouse infrastructure, crop science and agricultural technologies, would help reduce the water and environmental footprint of food production, while coping with growing food demand. Reducing animal-based foods can also play a role as well as shifting diets towards lab-grown meat. This could then cut the environmental costs of producing meat and eliminate the unethical treatment suffered by animals that are raised for food.

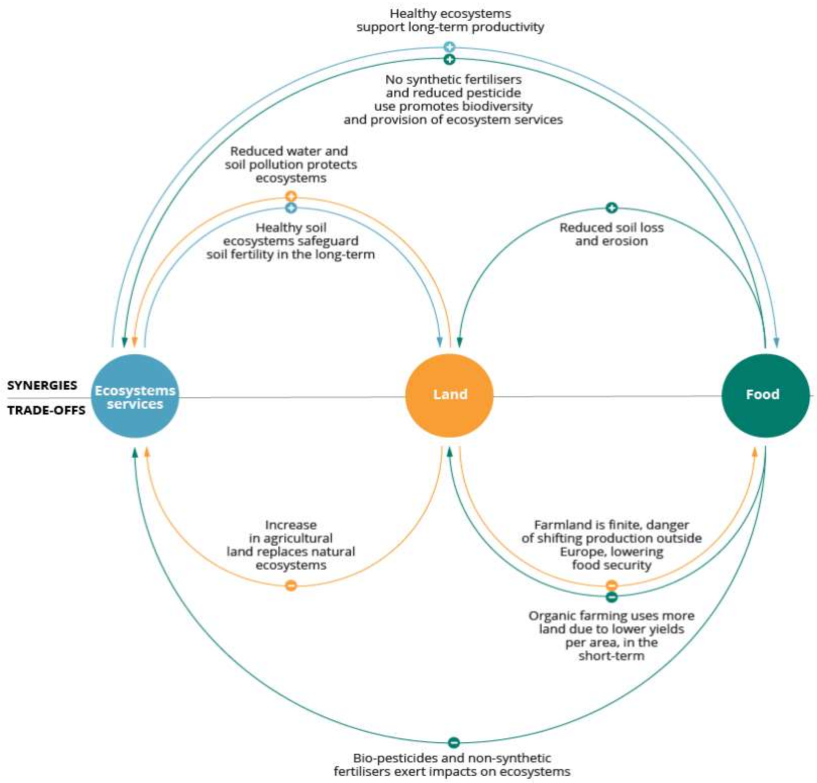
The Food and Land Use Coalition[73] is working to advance key transformation for how food is produced and consumed and how land is used to favour people, nature and climate. The hidden costs of global food and land use system total US$12 trillion, compared to a US$10 trillion market value of the food system. These costs come from obesity, undernutrition, pollution, pesticides, fertilisers, anti-microbial resistance, greenhouse gas emissions, food loss and waste, and natural capital destruction. These costs could rise to US$13 trillion by 2030 without action while a sustainable future scenario could see hidden costs reduced by US$5.7 trillion by 2030 and US$10.5 trillion by 2050.

Figure 12 provides an overview of the synergies and trade-offs associated with organic farming. Regarding synergies, organically farmed land has on average 30% more biodiversity than conventionally farmed land[74]. Soil fertility is higher, which can be positive for food production in the long term, and soil erosion may be reduced and its water-holding capacity increased[75]. Furthermore, organic farming reduces water pollution, as the use of pesticides and antimicrobials is reduced[76], which is also beneficial for aquatic biodiversity. The trade-offs are mostly short-term in nature, characterized by increase in the demand for land, lower yields per hectare, and higher water and energy requirement. However, these trade-offs are offset by the long-term synergies/benefits highlighted above.

[69] Consumer Goods Forum (September 2019). Scaling up the 10x20x30 initiative
[70] Consumer Goods Forum (March 2017) Research finds companies saved 17 dollars for every 1 dollar invested in reducing food waste
[71] National Geographic (September 2017). This tiny country feeds the world
[72] WWAP 2015; EEA 2020
[73] Food and Land Use Coalition 2019 www.foodandlandusecoalition.org/wp-content/uploads/2020/03/FOLU-Growing-Better-Report-Slides_web.pdf
[74] EC, 2021a
[75] EEA 2020a; Seufert and Ramankutty, 2017
[76] WWAP 2015; EEA 2020a

Forecasts are based on assumptions, estimates, views and hypothetical models or analyses, which might prove inaccurate or incorrect

Figure 12: 'Food-Land-Ecosystem Services' nexus



Source: European Environmental Agency Resource nexus and the European Green Deal (March 2022).

Investors could play a role by encouraging companies to strengthen the adoption of these types of production processes and techniques. Additionally, investors could encourage governments to strengthen their agricultural and innovation policies and budgets, in part by partnering with innovative countries such as the Netherlands.

3. Increasing company commitments to science-based nature targets

According to a S&P Global study[77], only 20% of the constituents of the S&P500 have made nature-related commitments. Their findings also show a significant divergence of company commitment by sector. One area of concern from an Earth Systems perspective is the low commitments among the food and beverage sectors, Figure 13. In addition, S&P Global work also revealed that commitments often did not have specific timelines.

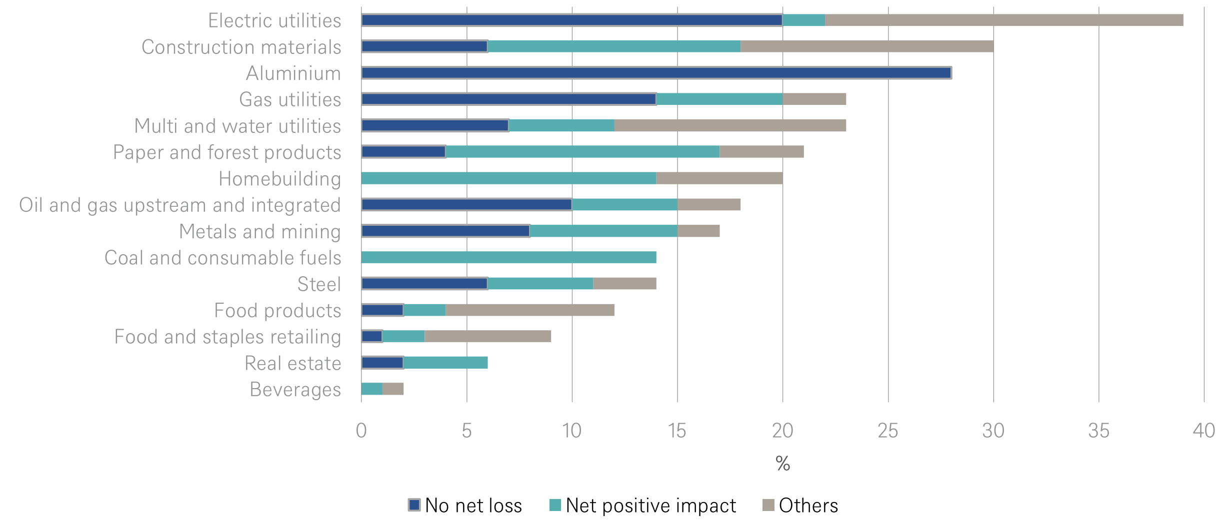
To address these shortcomings, biodiversity strategies need to be SMART, that is setting targets that are specific, measurable attainable, relevant and timebound. For example, when it comes to biodiversity commitments, initiatives such as Act4Nature have provided important guidance. In the case of agrochemical chemical commitments, these have included specific targets such as reducing freshwater intake, cutting non-recoverable industrial waste and increasing product sales in renewable or recycled products.

In September 2022, the Science Based Targets Initiative launched its Forest, Land and Agriculture (FLAG) Guidance. The program recognizes the important role that land-intensive companies can play in greenhouse gas reduction and the positive benefits for biodiversity. Few of these companies currently account for land-based emissions and, in many instances, these

[77] S&P Global (February 2022). Nature is climbing the agenda, but corporate diversity commitments remain rare

are hidden in a company's supply chain especially in grain and livestock commodities such as beef, chicken dairy, leather, maize, palm oil, pork, rice, soy and wheat as well as timber.

Figure 13: Percentage of companies per industry making nature-related commitments



Source: Corporate Sustainability Assessment 2021 (February 2022. Data as of November 2021. No net loss means that damages linked to business activity are offset by at least equivalent gains, avoiding a net loss of biodiversity and ecosystem services. Net positive impact means that corporate actions on biodiversity, such as habitat protection, are greater than the impact from its business activity. Examples of "other" commitments include: No deforestation; no peat; no exploitation. Results based on responses from 1,300 companies.

4. Investor engagement and public advocacy to natural capital

Examples of engagement themes targeted towards natural capital include the following:

Biodiversity – Natural capital investment, including restoration of carbon-rich habitats and climate friendly agriculture, is recognized as an important pillar of fiscal recovery plan since it offers high economic multipliers and positive climate impacts[78]. In terms of engagement points, investee companies should work towards establishing biodiversity and environmental protection standards and conduct independent review processes. Further, investee companies need to prevent and mitigate accidents and spills that seriously damage the environment and/or affect communities, including immediate coordination with the authorities and transparent reporting to stakeholders.

Deforestation –Commitments in this area have grown over recent years with the global leaders pledge at COP26 to end deforestation by 2030. In addition, the Investors policy dialogue on deforestation initiative established in July 2020. Soil quality, erosion, contamination and conservation are other important issues which investee companies should be encouraged to assess.

Water –The availability of freshwater resources globally has become a threat to human and ecosystem health. The water crisis is also exacerbated by climate change, making it even more urgent to drive capital market actors – including large institutional investors and major corporations – to address water issues[79]. As part of engagement with companies on water risk, investees need to be encouraged or ultimately mandated to report and act on such issues as their freshwater use and setting water reduction and recycling targets. Participation in investor collations, such as the Valuing Water initiative[80] launched in August 2022, should be encouraged.

[78] Hepburn et al. (2020), Will COVID-19 fiscal recovery packages accelerate or retard progress on climate change?, Smith School Working Paper 20-02

[79] Excerpts from the "The Valuing Water Finance Initiative" by Ceres https://www.ceres.org/water/valuing-water-finance-initiative

[80] Ceres, Valuing Water Initiative (August 2022). https://www.ceres.org/water/valuing-water-finance-initiative

Oceans - Investor engagement with their investee companies should focus on outlining possible key performance indicators (KPIs), based on, for example, the UNEP FI guidance in collaboration with WWF Germany. These initial KPIs are focused on understanding a company's activities versus its stated goals with regards to the sustainable blue economy.

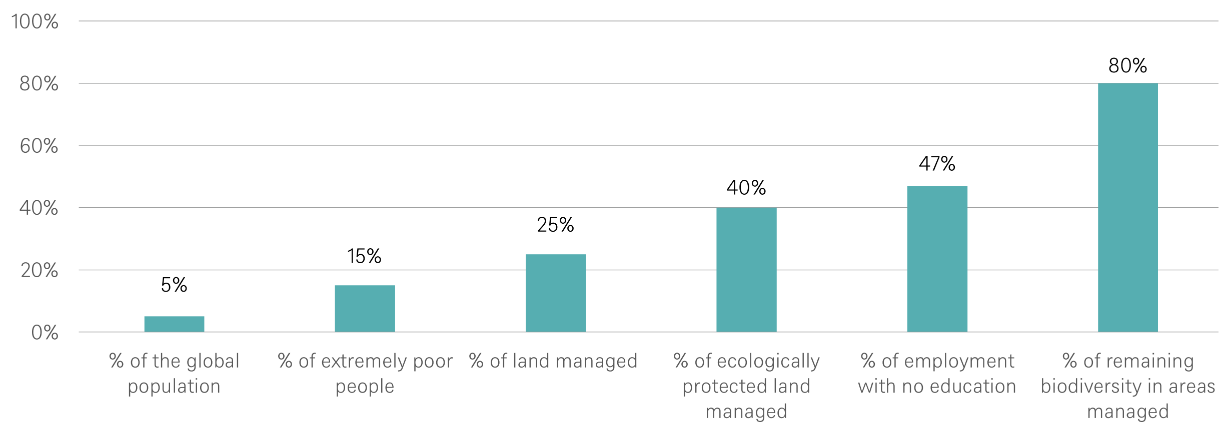
5. Supporting the Just Transition and the role of indigenous communities

A just transition for nature has become a new area for investor attention[81]. This looks to integrate human rights and labour standards alongside climate and biodiversity action. Indigenous people are important in this regard as this refers to a worldwide community of 500 million people residing across 90 different countries. They are the descendants of those who have lived in a specific geographic area before its colonisation and who have largely retained their own social, economic, cultural and political practices. While representing just 5% of the global population, roughly 80% of the remaining biodiversity rich areas of the planet are managed or inhabited by indigenous people[82], Figure 14.

The UN Declaration on the Rights of Indigenous Peoples grant these communities a specific right to free, prior and informed consent to land use projects, in principle allowing them to withdraw their consent at any stage of a development[83]. However, conflicts between business interests and indigenous people are common and while some companies try to minimise adverse impacts on indigenous people, this is typically the exception rather than the rule. The sectors most prone to interfere with these areas and indigenous groups include mining, oil and gas pipelines and transmission lines, large-scale construction, forestry, pharmaceuticals and biotechnology.

We believe that stronger participation of the indigenous peoples in the formal economy and sharing economic development profits can create its own benefits. As one expert recently put it, "The future of our planet lies in indigenous ways of living on the earth[84]." The indigenous peoples in Australia, Brazil and Namibia are just a few examples of how these communities can manage important ecosystems better than common business management practices[85]. Enabling a better future for indigenous peoples is essential to safeguarding our climate and biodiversity.

Figure 14: Measurements of indigenous communities as a proportion of global population



Source: DWS Investments UK Ltd analysis as of August 2021, Nature Sustainability July 2018, World Bank March 2021, UN August 2021

[81] LSE, Grantham Research Institute (August 2022). Just Nature: How finance can support a just transition at the interface of action on climate and biodiversity
[82] National Geographic (November 2018). Indigenous peoples defend Earth's biodiversity – but they're in danger
[83] UN Human Rights Office of the High Commissioner, August 2018
[84] Jon Waterhouse, Indigenous Peoples Scholar at the Oregon Health and Science University, quoted in National Geographic, November 2018.
[85] Corrigan et al. Sept 2018 Biological Conservation. www.sciencedirect.com/science/article/abs/pii/S0006320718306700?via%3Dihub

6. Promoting an Earth Systems' taxonomy

There is a growing recognition of investor engagement beyond climate change, focusing on natural capital – as is evident from the extensive projects undertaken by GRI, TNFD, One Planet, CDP, and the UN Research Institute for Social Development[86]. The review of GRI 304: Biodiversity 2016 is a priority project for the Global Sustainability Standards Board (GSSB), with expected completion by the middle of next year[87].

Recently, the Taskforce for Nature-related Financial Disclosures (TNFD) launched a pilot program with 23 of its member companies. The companies, with a total market value of USD$ 1.3 trillion and from North and South America, Europe, Asia and the Middle East, will feed important insights into the development of the TNFD beta framework before its final release in September 2023[88]. At the same time, the EU Platform on Sustainable Finance continues to work towards the other four environmental objectives in the EU Taxonomy (Sustainable use and protection of water and marine resources; Transition to a circular economy; Pollution prevention and control; and Protection and restoration of biodiversity and ecosystems). Another pertinent example is the PBAF[89] standard, which provides financial institutions with practical guidance on biodiversity impact and dependency assessments and define what is needed for these assessments to deliver the information to financial institutions.

Despite the growing importance of non-financial disclosures, the existing fragmentation of the sustainability reporting landscape creates difficulties and uncertainties in collecting and publishing comprehensive and comparable sustainability data. The variety of sustainability standards, frameworks, and definitions together with numerous different indicators and metrics create further challenges for companies to focus their efforts on strategic and meaningful disclosures. In this context, the mandate of the IFRS cross-jurisdictional working group to align global sustainability reporting requirements is commendable. However, the ISSB needs to ensure continued coordination and cooperation with jurisdictional authorities to prevent further regulatory fragmentation.

While there are merits in an Enterprise Value approach, the single materiality / climate change focus is disappointing given the rise of the sustainable investor, who clearly cares about assessing the impact financial capital has on society and the environment. Isolating climate from other environmental factors is like presenting P&L without Balance Sheet and Cash Flow, making it of little use for investor analysis.

This report, in addition to our 2021 whitepaper[90], demonstrate the strong links between climate and other risks (biodiversity, land and freshwater). We therefore need to examine climate risk alongside the other dimensions of the biosphere. This will then allow investors to conduct the proper due diligence required in assessing environmental risk and opportunities. For example, we have been conducting research that show it is possible to price the impact economic activities have on the environment and the potential impact if such costs were internalised[91].

There is therefore a tangible need for a broader Earth Systems' taxonomy which moves us beyond the current efforts on climate and single materiality. Otherwise, there will be material implications on capital allocations, the proper working of financial markets, and the nexus of Earth Systems.

Contributor

Jay Joshi
Research House

[86] UNRISD (November 2022). UN releases manual for companies to conduct authentic, context-based sustainability assessments
[87] Global Reporting Initiative 2021 https://www.globalreporting.org/standards/standards-development/topic-standard-project-for-biodiversity/
[88] TNFD Pilot Project (October 2022) https://www.wbcsd.org/Overview/News-Insights/General/News/TNFD-pilot-program
[89] Partnership for Biodiversity Accounting Financials (2022) https://www.pbafglobal.com/standard
[90] Oceans & Climate – Exploring the Nexus (October 2021) - https://www.dws.com/en-gb/insights/global-research-institute/oceans-climate-exploring-the-nexus/
[91] Financial implications of addressing water externalities in the apparel and meat industries (December 2021) - https://www.dws.com/en-gb/insights/global-research-institute/financial-implications-of-addressing-water-externalities-in-the-apparel-and-meat-industries/

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