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Interim report

The interconnected Challenges of Climate Change, Biodiversity Loss and Environmental Pollution

Drivers, Interdependencies and Impacts of the Triple Planetary Crisis

by:
Doris Knoblauch, Charlotte Felthöfer,
Yannick Heni, Natalia Burgos Cuevas, Aaron Best
Ecologic Institute, Berlin

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Umweltbundesamt
Wörlitzer Platz 1
06844 Dessau-Roßlau
Tel: +49 340-2103-0
Fax: +49 340-2103-2285
buergerservice@uba.de
Internet: www.umweltbundesamt.de

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Ecologic Institut
Pfalzburger Str. 43/44
10717 Berlin
Germany

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Abstract: The Interconnected Challenges of Climate Change, Biodiversity Loss and Environmental Pollution – Drivers, Interdependencies and Impacts of the Triple Planetary Crisis

The environmental crises of climate change, biodiversity loss, and environmental pollution now constitute a system interlinked 'triple planetary crisis', driven by the increased extraction and processing of resources, ranging from fossil fuels to minerals and biomass and underlying systemic social inequities. Marginalized communities bear the heaviest burdens but often have the least power to influence outcomes, especially Indigenous Peoples, youth, ethnic minorities and Small Island Developing States (SIDS).

However, current research and policy responses remain fragmented, leaving important gaps in the understanding of systemic linkages and impacts on both ecosystems and people. This report helps bridge that gap by providing a cross-sectoral analytical perspective. It identifies (1) the shared drivers and interactions that connect these crises, (2) illustrates their impacts on ecosystems and human health, and (3) highlights their socioeconomic effects, showing how the risks disproportionately affect especially vulnerable groups and areas (MAPA).

The report concludes that the feedback effects of the planetary triple crisis can only be effectively addressed through close collaboration across sectors and by consciously considering inequalities and vulnerabilities. There is a need for socially just and practically feasible solutions that enable a fair distribution of burdens and foster resilient societies and ecosystems.

Kurzbeschreibung: Die miteinander verbundenen Herausforderungen des Klimawandels, des Verlusts der biologischen Vielfalt und der Umweltverschmutzung – Ursachen, Wechselwirkungen und Auswirkungen der planetaren Dreifachkrise

Die Umweltkrisen des Klimawandels, des Verlusts der biologischen Vielfalt und der Umweltverschmutzung bilden heute eine miteinander verknüpfte planetare Dreifachkrise. Diese wird durch die zunehmende Förderung und Verarbeitung von Ressourcen, von fossilen Brennstoffen über Mineralien bis hin zu Biomasse, und durch zugrunde liegende systemische soziale Ungleichheiten verursacht. Marginalisierte Gemeinschaften sind von ihren Auswirkungen am stärksten betroffenen, haben auf diese aber oft am wenigsten Einfluss. Dies betrifft insbesondere indigene Gruppen, junge Menschen, ethnische Minderheiten und sog. kleine Inselentwicklungsländer (SIDS).

Die aktuellen Forschungsergebnisse und politischen Maßnahmen sind jedoch nach wie vor fragmentiert, sodass wichtige Lücken im Verständnis der systemischen Zusammenhänge und Auswirkungen auf Ökosysteme und Menschen bestehen bleiben. Dieser Bericht trägt durch eine sektorübergreifende analytische Betrachtung dazu bei, diese Lücke zu schließen. Er identifiziert (1) die gemeinsamen Treiber und Wechselwirkungen, die diese Krisen miteinander verbinden, zeigt (2) ihre Auswirkungen auf Ökosysteme und die menschliche Gesundheit auf und (3) untersucht die sozioökonomischen Auswirkungen sowie die Risiken für besonders vulnerable Gruppen und Gebiete (MAPA).

Der Bericht kommt zu dem Schluss, dass die Rückkopplungseffekte der planetaren Dreifachkrise nur durch eine enge Zusammenarbeit verschiedener Bereiche sowie durch das bewusste Berücksichtigen von Ungleichheiten und Verletzlichkeiten wirksam angegangen werden können. Zudem braucht es sozial gerechte und praktisch umsetzbare Lösungen, die eine faire Verteilung der Lasten ermöglichen und resiliente Gesellschaften und Ökosysteme bilden.

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List of abbreviations

Abbreviation	Explanation
ADHD	Attention deficit hyperactivity disorder
AFOLU	Agriculture, forestry, and other land uses
AMOC	Atlantic Meridional Overturning Circulation
AP	Agricultural Plastics
CE	Circular economy
CO_2	Carbon dioxide
COP	Conference of the Parties
COVID-19	Coronavirus disease
DPP	Digital Product Passport
ECHOES	Exploring Climate and Human Observations from the Global South[1]
EEA	European Environment Agency
EU	European Union
EoLGer	End-of-Life
GDP	Gross domestic product
GHG	Greenhouse gas
GSDR	Global Sustainable Development Report
IPBES	Intergovernmental Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
LPI	Living Planet Index
LULUCF	Land use, land use change and forestry
MAPA	Most affected people and areas
MNP	Micro- and nanoplastics
NDC	Nationally Determined Contributions (in Paris-Agreement)
N_2O	Nitrous oxide (laughing gas)
PFAS	Per- and polyfluoroalkyl substances
PIK	Potsdam Institute for Climate Impact Research
SIDS	Small island developing states
STEEP	Social, Technological, Economic, Environmental, Policy (method)
SVTEEG	Social, Values, Technological, Economic, Environmental, Governance (method)

[1] ECHOES is a working group composed of the following members: Laura Furquim, Mariya Antonosyan, Deepak K. Jha, Patrick Roberts, Veronica Zucarelli Freire, Danielle Viegas, Freg Stokes, Victor Iminjili, Gopesh Jha, Michael Ziegler, Rachel Rudd, Victor Andrade, Yoshi Maezumi, and Rebecca Lellau.

Abbreviation	Explanation
TWh	Terawatt hours (measuring units for energy)
UNEP	United Nations Environment Programme
UNEN	United Nations Economist Network
UNFCCC	United Nations Framework Convention on Climate Change
WEF	Water-energy-food (nexus)
WHO	World Health Organization

Glossary

Term	Explanation
Breadbasket	A region that produces large amounts of staple crops such as wheat, corn, or rice, usually due to fertile soil and favorable climate, making it vital for food supply.
Cascading effect	A process in which the impact of an initial event or disturbance triggers a sequence of secondary effects across interconnected systems, often amplifying the overall consequences.
Compounding risk	A situation where multiple hazards or stressors occur simultaneously or interact with one another, leading to combined impacts that are greater and more complex than the effects of each individual risk alone.
Local communities	A group of people with a longstanding relationship to a specific area, who have developed distinctive knowledge, practices, and cultural identities through their reliance on and management of local resources.

1 Introduction

"Humanity's future depends on pulling together, not apart, to overcome the triple planetary crisis: the crisis of climate change, the crisis of nature and biodiversity loss and the crisis of pollution and waste." Inger Andersen, UNEP Executive Director (UNEP, 2023)

The impact of human activity on the global environment has typically been categorized into three main issues: climate change, biodiversity loss, and environmental pollution. These challenges have also been understood and tackled largely as separate problems, each with its own set of specialists and policy approaches. However, a growing body of scientific research now highlights that these crises are fundamentally interlinked, sharing common drivers and reinforcing one another through feedback mechanisms (see i.a. Hellweg et al., 2023; Miao and Nduneseokwu, 2024; Richardson and al., 2023). This recognition has led to the emergence of the concept of the "triple planetary crisis". What were previously seen as separate environmental problems are now understood as part of a systemically interconnected crisis landscape. These threats are not unfolding independently; they are part of a single, interconnected system that poses escalating risks to planetary and human well-being" (Carney Almroth and Villarrubia-Gómez, 2024).

The triple planetary crisis is also not just an environmental phenomenon, but a fundamentally social and economic one. Its impacts are distributed unevenly, shaped by persistent inequalities of power, wealth, and responsibility. The resulting effects are deeply systemic in nature, not only affecting planetary boundaries but also human health and social dimensions (Herzog and Kondratjuk, 2024).

For these reasons, scholars now call for integrated approaches that break down traditional silos and address the interconnected nature of the triple planetary crisis. Only through systemic, cross-sectoral research and policy can societies respond effectively to these overlapping threats and chart a path toward a more resilient and equitable future (see e.g. Drenckhahn et al., 2020; Sigmund et al., 2023). While the need for integration is now widely recognized in principle, most research and policy responses still struggle to move beyond fragmented analyses and single-issue solutions. There remain significant gaps in understanding how the drivers, feedback, and impacts of the triple planetary crisis operate together across ecological, health, and socioeconomic dimensions, particularly when it comes to the lived realities and vulnerabilities of the most affected people and areas.

Responding to the urgent need for a holistic perspective on the triple planetary crisis, this report examines the fundamental interlinkages among climate change, biodiversity loss, and pollution.[2] Using the SVTEEG analytical framework, the analysis first maps the common drivers and feedbacks that connect these crises, highlighting how patterns of resource use, land degradation, and economic activity interact across planetary boundaries. The report then assesses the impacts of the triple planetary crisis - first focusing on ecosystem integrity and human health and subsequently exploring the socioeconomic consequences. By applying a Most Affected People and Areas (MAPA) perspective, the analysis further examines how vulnerabilities and risks are distributed across different regions and communities. Together, the report offers an integrated overview of the systemic risks and cascading impacts of the triple planetary crisis, providing a foundation for further coordinated research and action.

[2] We use the term 'triple planetary crisis' because it is still the most common term in the literature, and it focuses on the three main crises. However, the term 'polycrisis' is also used (Herzog and Kondratjuk, 2024; Kimpeleer and Erdmann, 2025; Quagliarotti, 2023), particularly to describe overlapping systemic crises that also include pandemics or wars. This highlights that overlapping crises negatively affect each other and endanger water, energy and food security. Therefore, while we primarily use the term 'triple planetary crisis', we also use the term 'polycrisis'.

2 Analytical framework: Why a systemic and inclusive view is necessary

In the face of escalating global environmental challenges, the limitations of conventional, siloed approaches are becoming increasingly evident. Addressing climate change, biodiversity loss, and pollution as isolated phenomena fails to reflect the deeply interconnected nature of these crises. A systemic and inclusive view is therefore indispensable—not only for understanding the complex feedback loops between environmental, economic and social systems (including health), but also for crafting responses that are both effective and equitable.

Scientific research has demonstrated that the drivers of climate change, biodiversity loss, and environmental degradation are closely entangled (Brocchi, 2024; e.g. Carney Almroth and Villarrubia-Gómez, 2024; Casonato et al., 2024; Corbane et al., 2024; Destoumieux-Garzón et al., 2022; Drenckhahn et al., 2020; He and James, 2021; Onyenekwe et al., 2022; Richardson and al., 2023; Tan et al., 2024; Villarrubia-Gómez et al., 2024). For example, Destoumieux-Garzon et al. (2022) highlight how a range of anthropogenic activities—such as greenhouse gas emissions, overexploitation of resources, and land-use changes—contribute simultaneously to multiple forms of planetary stress:

> *"Scientific evidence shows that human activities such as greenhouse gas emissions, overuse of natural resources, pollution, expansion of agriculture and livestock, wildlife exploitation and changes in land use (deforestation, mining and infrastructure development) are causing climate change and climate variability, biodiversity loss, habitat destruction, land degradation and landscape modifications. In turn, these environmental changes have been hypothesized to be direct or indirect factors causing disease emergence and expansion, i.e., epidemics and pandemics."* (Destoumieux-Garzón et al., 2022, p. 6)

This quote underscores the systemic nature of the crisis. Environmental degradation is not only interlinked but also closely tied to human and planetary health. A polycrisis thus unfolds through these feedback loops, wherein environmental change exacerbates social vulnerabilities and vice versa (GSDR, 2023).

The interdependencies between climate change and the loss of biodiversity strongly illustrate the phenomenon of entanglement. As IPBES (2024a) notes, these two crises are not only co-occurring, but mutually reinforcing:

> *"Biodiversity is declining in all regions of the world and at all spatial scales, impacting ecosystem functioning, water availability and quality, food security and nutrition, human, plant and animal health and resilience to the impacts of climate change. Biodiversity loss and climate change are interdependent and produce compounding impacts and impacts that threaten human health and well-being."* (IPBES, 2024a, p. 6)

By isolating these issues, policy responses risk overlooking the cascading effects that one crisis can have on another. For example, biodiversity degradation weakens nature's ability to mitigate climate risks through ecosystem services such as carbon sequestration, water regulation, and disease buffering.

In addition to recognizing systemic interdependencies, navigating the planetary crisis requires inclusive governance and research processes (IPBES, 2024b, 2024a). The challenges at hand are embedded in diverse cultural, ecological, and socio-economic contexts, each with different knowledge systems and priorities (IPBES, 2019). Inclusivity must be embedded from the outset. It depends on an intentional and early-stage approach that acknowledges diverse knowledge systems, addresses issues across different scales, allocates appropriate time and resources, and actively involves a broad network of stakeholders with varying perspectives (Carroll et al., 2023; IPBES, 2024a). In this sense, inclusivity is not merely a normative aspiration but a methodological necessity for working across scales, systems, and sectors. It enhances the relevance, legitimacy, and resilience of responses to the multiple crises by ensuring that diverse forms of expertise and experience are brought to the table (IPBES, 2024b). Understanding and addressing the converging planetary crises of our time requires a shift from narrow, issue-specific interventions to systemic and inclusive approaches. This shift entails acknowledging complex interdependencies, engaging diverse actors, and co-producing knowledge that reflects the realities of a world in crisis (GSDR, 2023; IPBES, 2024a).

3 Drivers and interdependencies of the triple planetary crisis

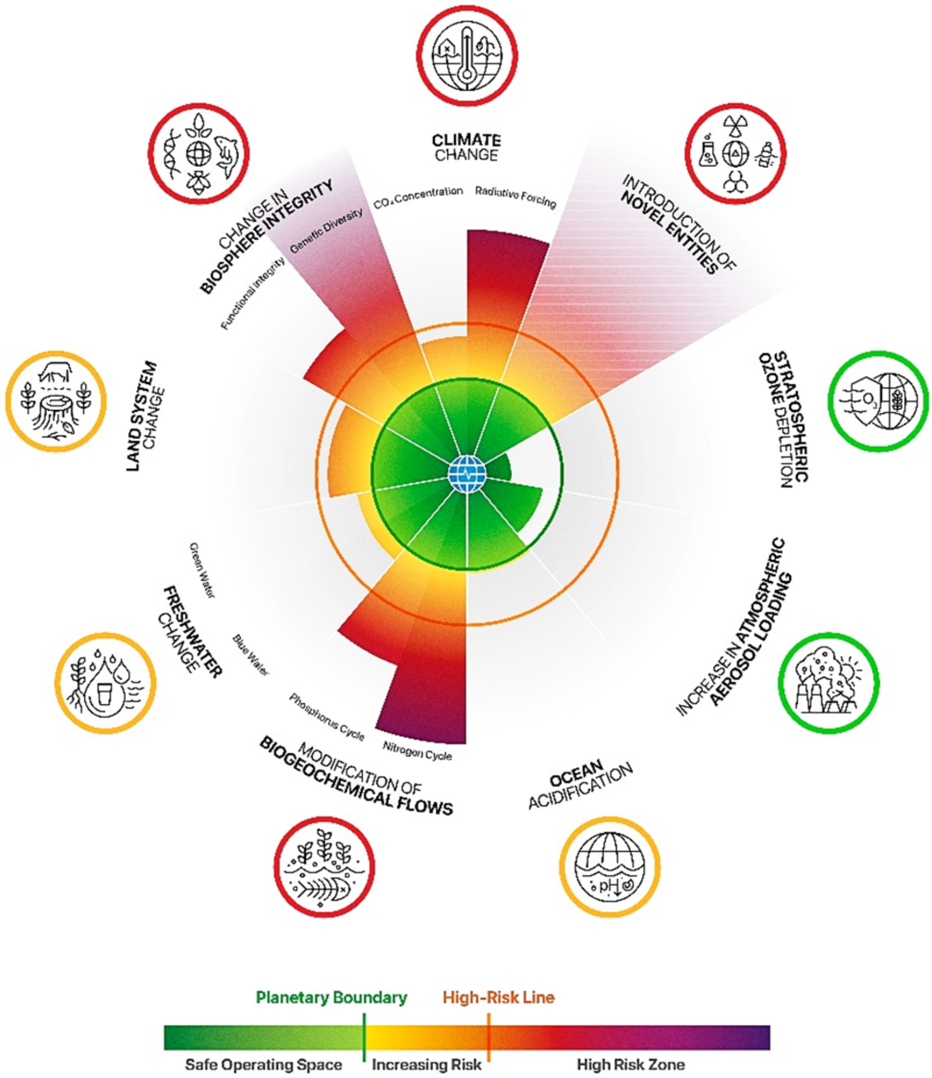
The planetary crises of climate change, biodiversity loss, and pollution share underlying drivers – such as fossil fuel dependence, unsustainable resource use, and systemic inequalities – and interact through complex feedback. Their interlinkages mean that pressures in one domain can intensify risks in others, resulting in mutually reinforcing impacts that threaten both natural systems and human well-being (see also Felthöfer et al., 2025). These dynamics mean these crises (and many approaches to addressing them) are fundamentally interdependent in nature.

Planetary boundaries and systemic risks

The planetary boundaries framework assesses the extent to which humanity remains within the limits necessary to avoid destabilizing critical Earth system processes. climate change, land system change, freshwater change, biosphere integrity, biogeochemical flows and novel entities. In 2025, ocean acidification left the safe operating space for the first time (Sakschewski et al., 2025). This means that more than two thirds of the planetary boundaries have now been transgressed. These escalating impacts clearly illustrate the systemic pressures exerted by the triple planetary crisis and expose how the crises are not independent but are fundamentally interconnected through nonlinear, dynamic interactions (Richardson and al., 2023). Exceeding the boundary of biogeochemical flows of nitrogen and phosphorus, for instance, affects other boundaries such as freshwater change, biosphere integrity, and land system change. Pollution, in the form of excess nutrient inputs, drives biodiversity loss and destabilizes ecosystem resilience (Rockström et al., 2023). Also, climate change risks are becoming increasingly complex, with climatic and non-climatic drivers interacting to produce compound and cascading effects across sectors and regions (IPCC, 2023b).

As more boundaries are crossed, the likelihood of crossing ecological and societal tipping points increases (Rockström et al., 2023). While initial effects may be local, their impacts propagate globally through teleconnections, i.e. long-distance linkages across regions and systems. This propagation occurs via interconnected social, economic, and environmental systems. These stressors interact to push both ecosystems and social systems toward their respective tipping points, potentially resulting in irreversible, abrupt changes and cascading effects (Scheffran, 2023). Ecosystem degradation is interconnected across scales, so disturbances in one region can amplify risks both nearby and at great distances (Frey et al., 2023).

Figure 1: The status of the nine Planetary Boundaries as of 2025.



Source: Potsdam Institute for Climate Impact Research (Sakschewski et al., 2025).

Direct and indirect drivers of the triple planetary crisis

The underlying causes of these planetary crises are also complex and multi-dimensional. The transgression of Earth system boundaries and the escalation of the triple planetary crisis reveal deep systemic failures within human societies (Haderer et al., 2023). The triple planetary crisis is propelled by both indirect and direct drivers. Indirect drivers encompass broad societal factors - such as economic, demographic, cultural, and technological change - that shape the context for environmental change. Among these, the increasing global interconnectedness of material and informational flows is one important amplifier, accelerating the spread and interaction of environmental risks across sectors and regions (Diller, 2024). Indirect drivers influence the scale and nature of direct human activities like land-use change, resource extraction, and emissions, which ultimately give rise to pollution, biodiversity loss, and climate change. Thus, the triple planetary crisis is primarily driven by the interplay of indirect and direct drivers operating across economic, social, and environmental systems (IPBES, 2024a), highlighting its multi-dimensional nature (Herzog and Kondratjuk, 2024).

Structural inequalities and root causes

Underpinning these trends are deep-seated structural causes, including widespread disconnection from and domination over both nature and marginalized people, the concentration of power and wealth, and the prioritization of short-term, individual, and material gains. These root causes perpetuate exploitation and marginalization, often with historical roots in colonialism, slavery, and the modern capitalist economy, and continue to undermine efforts to pursue transformative change (IPBES, 2024b). As a result, the triple planetary crisis is not simply environmental but reflects intertwined social, cultural, political, scientific, and economic inequalities, with MAPA often having the least power to influence outcomes (Herzog and Kondratjuk, 2024; Wittmer et al., 2021).

Sectoral amplifiers: the energy, agriculture and construction sectors' role in the triple planetary crisis

The triple planetary crisis is driven by the increased extraction and processing of resources, ranging from fossil fuels to minerals and biomass. Agriculture and forestry alone are responsible for over 90% of biodiversity loss and water stress caused by land use (UNEP, 2024). Farming occupies over one-third of the planet's land area and consumes nearly three-quarters of accessible freshwater supplies. This large-scale use of land and water resources makes agriculture the most significant direct pressure on terrestrial and freshwater ecosystems, driving biodiversity loss substantially. According to the Living Planet Index (LPI), the average size of monitored wildlife populations has shrunk by 73% globally since 1970 (WWF, 2024). Numbers are reaching a decline of 95% in Latin America and the Caribbean compared to less drastic declines in Europe and Central Asia with 35% and North America 39%. This can be partly attributed to large-scale impacts on biodiversity before 1970 in these regions and successful conservation efforts (WWF, 2024). Impacts on biodiversity mainly occur at the start of the value chain with about 75% of land-related biodiversity impacts stemming from agriculture, forestry accounting for 23% (UNEP, 2024). Over 90% of cultivated crop varieties are no longer grown in farmers' fields, and about half of the breeds of numerous domesticated animals have disappeared. This erosion of agricultural biodiversity reduces the sector's resilience, making food systems more susceptible to pests and extreme local weather events (WWF, 2024).

Roughly one-quarter of global greenhouse gas emissions stem from land clearing, crop cultivation, and fertilizer use, with animal-based food production responsible for about three-quarters of that share (IPBES, 2019). 10-12% of global GHG emissions stem directly from agriculture, rising to almost one-quarter when land-use change is included (Miao and Nduneseokwu, 2024). In 2022, agriculture released 16.2 billion tonnes of CO_2, which is over 10% more than in 2000. Most emissions come from crop and livestock production, with livestock being the largest contributor (Pereira et al., 2025). Agriculture also contributes significantly to global nitrous oxide (N_20) emissions, a potent GHG with a higher warming potential than CO_2 and a longer atmospheric lifetime. By 2018, methane (CH_4) and N_20 emissions had risen by 14% compared to 2000, mainly due to livestock farming (Pereira et al., 2025). Fertilizer use releases NO_2 through soil microbial processes, accounting for about 2-3 % of global GHG emissions. N_2O is also released through manure management and biomass burning (Miao and Nduneseokwu, 2024). In monocultures, tilling the soil can raise greenhouse gas emissions because it speeds up the breakdown of soil organic matter and damages soil structure. In wetlands, the use of herbicides like glyphosate harms microbial communities and further increases emissions (Pereira et al., 2025).

Agricultural activities also introduce large amounts of plastics to the terrestrial and marine environment: In 2019, at least 12.5 million tonnes of plastics were used globally in agriculture, illustrating how material flows in food production systems are directly connected to pollution and land system change (Villarrubia-Gómez et al., 2024).

Agricultural Plastics (AP) are used e.g. to regulate harvest times and protect against soil erosion while also reducing i.a. water, energy and herbicides inputs. While this supports resource efficiency to a certain extent, the production of APs and its increasing demand is estimated to be responsible for 98 Mt CO_2 by 2050, more than doubling their emissions expected in 2030 (Briassoulis, 2023).

End-of-Life (EoL) mismanagement of AP, including discarding, burning, or rototilling them into the soil, lead to their degradation and fragmentation into micro- and nano-plastics (MNP). The burning of AP and the accumulation of MNP in the environment increases pollution and contributes to GHG emissions (Briassoulis, 2023). MNP contamination in soils, whether from conventional or so-called biodegradable plastics, fundamentally undermines soil structure, biodiversity, nutrient cycling, and carbon sequestration, with potentially profound implications for medium- and long-term food production (Yates et al., 2025).

Beyond agriculture, the energy sector is central to the triple planetary crisis, acting both as a primary source of greenhouse gas emissions and as a driver of land use change, resource extraction, and pollution. Fossil fuel extraction and combustion accounts for about three-quarters of global CO_2 emissions, making energy production the single largest driver of anthropogenic climate change (EDGAR, 2024). The impacts of the energy sector extend beyond the atmosphere: extraction, processing, and use of fossil fuels drive extensive land use change, habitat fragmentation, and chemical pollution, all of which intensify biodiversity loss and ecosystem degradation. Transitions to renewable energy systems are a prerequisite to substantially reduce environmental pressures. Nevertheless, even as economies transition to renewable energy systems, their large-scale deployment can result in further land conversion and resource pressures, underscoring the complex, systemic links between the energy sector, environmental pollution, and biodiversity decline and the need for careful planning to minimize trade-offs and ensure that renewable energy expansion maximizes ecological co-benefits (Ellwanger and Bogo Chies, 2025; Pörtner et al., 2021).

The construction sector compounds these challenges as the built environment is not only a major consumer of resources and energy but also a significant source of environmental pressures across all dimensions of the triple crises. The sector alone accounts for almost 40 % of global energy and process-related CO_2 emissions, making it a central contributor to climate change (Soust-Verdaguer et al., 2022). At the same time, the sector's demand for materials and land accelerates biodiversity loss, while the generation of waste and the use of synthetic chemicals contribute to environmental pollution.

Systemic interactions and feedback loops across the triple planetary crisis

According to IPCC (2023b) projections, average global temperatures could rise by up to 4.4 degrees Celsius by 2100, under a high GHG emissions scenario. Such a rapid rate of change would far exceed the adaptive capacity of most ecosystems, increasing the risk of widespread collapse (Brocchi, 2024). At the same time, the biosphere's limited capacity to absorb natural substances such as carbon dioxide or methane is projected to decline further, leading to greater accumulation of greenhouse gases in the atmosphere. This weakening sink capacity is partly driven by the intensification of climate change itself – for instance, warming, drought, and ecosystem degradation reduce the ability of forests, soils, and oceans to absorb carbon.

However, this feedback loop can be mitigated through steep emission reductions and ecosystem protection, which help maintain and enhance the biosphere's capacity to act as a carbon sink (IPCC, 2023b).

Land and sea use change remain the most significant direct drivers of biodiversity decline, primarily through habitat loss, degradation, and fragmentation. However, climate change is increasingly recognized as a major driver in its own right and is projected to surpass other pressures if current trends accelerate, while also amplifying other threats such as land and resource use, pollution, and ecosystem fragmentation (IPBES, 2024b). Both climate change and biodiversity loss are driven by common anthropogenic pressures, namely overexploitation of resources, energy demand, and land transformation. These crises reinforce each other through feedback mechanisms: higher greenhouse gas concentrations lead to an increase in average atmospheric temperature, extreme weather events, and altered aquatic systems, harming biodiversity (Drenckhahn et al., 2020). In return, biodiversity loss especially of phytoplankton and vegetation reduces carbon storage and regulation of the water and nitrogen cycles, accelerating climate instability (see also Felthöfer et al., 2025). As biodiversity and ecosystem integrity decline, so does the adaptive capacity of ecosystems and societies, raising the risk of tipping points and cascading systemic disruptions (Pörtner et al., 2021).

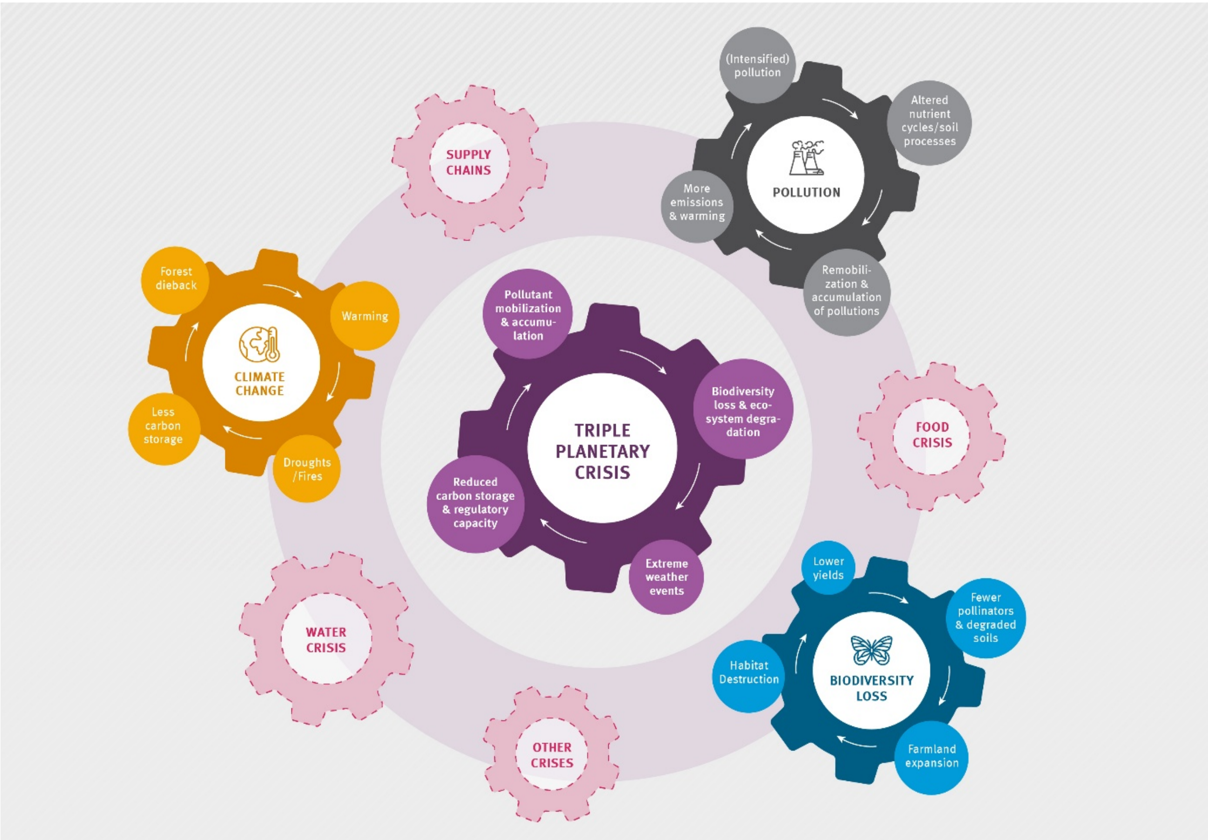
Climate change and the water-energy-food nexus are tightly interlinked through a network of bidirectional feedback. Climate-driven phenomena, such as rising temperatures, shifting precipitation, and extreme weather events, directly destabilize the availability and allocation of water, energy, and food resources, intensifying resource scarcity and competition between sectors. At the same time, efforts to meet growing demand for water, energy, and food, e.g. through an increased fossil fuel extraction, intensive agriculture, and desalination, frequently amplify greenhouse gas emissions and environmental degradation, further fuelling climate change and exacerbating vulnerabilities within the nexus (Quagliarotti, 2023). For example, the widespread use of neonicotinoid insecticides in intensive agriculture not only leads to dramatic declines in pollinator populations, undermining food security, but also contributes to the contamination of water resources and accelerates biodiversity loss (Drenckhahn et al., 2020). Air and water pollutants from energy systems, including heavy metals, hydrocarbons, and particulates, have direct toxic effects on both terrestrial and aquatic species (Ellwanger and Bogo Chies, 2025).

Pollution is a further amplifier, with chemical contaminants impairing reproduction, growth, and survival of exposed species, in some cases driving local population declines or extinctions. These effects cascade through food webs, fundamentally altering the structure and function of ecological communities (Schäffer et al., 2023). For example, when microplastics accumulate in soils at high concentrations, they can modify soil structure, water retention, and microbial community composition. These changes, in turn, can disrupt nutrient cycling and microbial processes, which under certain conditions may lead to increased greenhouse gas emissions and thereby exacerbate climate change (Lan et al., 2025; Yates et al., 2025). Persistent organic pollutants (POPs) are synthetic chemicals used in pesticides, industrial applications, and consumer products. They circulate globally, with their emissions and transport depending on atmospheric and oceanic conditions. Climate change affects these conditions through mechanisms such as increased ice melt, sediment remobilization, and atmospheric deposition and consequently alters the dynamics of POPs in marine environments, such as in the northern polar region where they accumulate (Noyes et al., 2025).

Plastic production is fundamentally tied to fossil fuel use, with 99% of plastics made from fossil-based feedstocks and significant emissions generated throughout their life cycle - from raw material extraction to waste management (Carney Almroth and Villarrubia-Gómez, 2024). In 2019, global production of primary plastics was responsible for about 5.3 % of total global GHG emissions (excluding the AFOLU sector), a share expected to double by 20250 (Karali et al., 2024). Most emissions arise during raw material sourcing and production, with an additional significant share contributed by end-of-life processing and waste. Moreover, plastics can affect climate indirectly by altering biogeochemical cycles and even influencing albedo and melting in the cryosphere through microplastic deposition. This growing contribution to greenhouse gas emissions underscores the strong intersection between pollution and climate change (Carney Almroth and Villarrubia-Gómez, 2024).

These interlocking pressures illustrate how the triple planetary crisis extends beyond environmental systems, raising fundamental risks for human health and well-being. The following chapter examines these impacts in detail.

Figure 2: Feedback loops of the triple planetary crisis



Source: Own illustration, Ecologic Institute.

4 Impacts of the triple planetary crisis on human and ecosystem health

The triple planetary crisis has far-reaching consequences for both human and ecosystem health. Each of the three crises independently drives significant biophysical transformations that threaten the stability of terrestrial, freshwater, and marine ecosystems, as well as physical and mental health and human rights (see also Felthöfer et al., 2025). This is particularly true where highly vulnerable regions and climate hazards overlap (IPCC, 2023b).

Impacts on ecosystem health

Pollution and other stressors linked to the triple planetary crisis are increasingly undermining the integrity of ecosystems. In agricultural soils, widespread microplastic contamination disrupts carbon, nitrogen, and phosphorus cycling by altering soil structure and microbial activity. Chemical pollutants, including plastics, nitrates, metals, and antibiotics, further degrade soil microbial diversity (Yates et al., 2025). As these contaminants accumulate, soils become less able to filter pollutants and sustain plant growth, which intensifies biodiversity loss and can result in feedback loops that further destabilize ecosystem processes (Sharma et al., 2025). Reduced soil fertility, destabilized soil aggregates, and impaired water movement increase greenhouse gas emissions and lower plant productivity, threatening food security (Lan et al., 2025). Toxic chemicals also harm both target and non-target species, thereby further destabilizing ecosystem networks (Drenckhahn et al., 2020).

These ecosystem-level changes compromise the self-regulating capacity of soils and natural systems, making them increasingly vulnerable to additional environmental pressures and diminishing their ability to provide essential life-supporting functions.

Impacts on human health

The loss of ecosystem integrity and functionality not only threatens natural systems but also has immediate and far-reaching implications for human health, as the disruption of ecosystem services and increasing exposure to environmental contaminants directly affect wellbeing and disease risk (IPCC, 2022). The ongoing loss of biodiversity and ecosystem integrity therefore poses immediate and indirect risks to population health, as disruptions to natural systems compromise both direct benefits such as pharmaceutical resources and indirect benefits by threatening clean water, air and food security (Frey et al., 2023; Schmid and Schwienhorst-Stich, 2023).

More frequent and intense extreme weather events - such as floods, storms, and heatwaves - not only cause direct injury but can also damage health infrastructure and disrupt access to medical care, leading to increased mortality and vulnerability during crises (IPCC, 2022). The World Health Organization estimates that between 2030 and 2050, climate change will cause approximately 250,000 additional deaths per year worldwide due to malnutrition, malaria, diarrhoeal disease, and heat stress - with more than half of these deaths projected to occur in Africa (IPCC, 2022; WHO, 2021). Importantly, this figure does not include all potential climate-sensitive deaths - such as those caused by air pollution, extreme weather events, displacement, or the broader cascading impacts of ecosystem decline - meaning the true health burden of climate change is likely considerably higher.

Pollution in all its forms, including air, water, soil, and chemical pollution, is now recognized as a leading driver of premature mortality worldwide, responsible for an estimated 9 million deaths per year—more than AIDS, tuberculosis, and malaria combined (Ihsan et al., 2024). Plastics, in particular, have now been detected throughout food webs and in human tissues, including drinking water, breast milk, the placenta, lung tissue, and the bloodstream. The presence of plastics in the environment is also increasing the transmission and severity of vector-borne diseases such as dengue, malaria, and zika, risks that are projected to intensify further with rising global temperatures (Villarrubia-Gómez et al., 2024). During the last decades, PFAS (per- and polyfluoroalkyl substances) were used for non-stick pans, single-use food packaging, and stain-resistant textile, amongst others. However, they have severe implications on health. Research indicates that exposure to PFAS during pregnancy and early childhood is associated with restricted foetal growth, birth defects, and developmental delays, along with cognitive and behavioural issues such as reduced IQ, attention deficit hyperactivity disorder (ADHD), and anxiety. In children and adolescents, PFAS exposure has also been linked to a range of health concerns, including ADHD, behavioural problems, early onset of puberty, kidney disorders, disruptions in thyroid function, and changes in reproductive hormones (Dehghani et al., 2025). Environmental changes driven by human activities are key drivers of disease emergence and expansion, raising the risk of epidemics and pandemics linked to altered landscapes and disturbed ecological balances (Daszak et al., 2020; Destoumieux-Garzón et al., 2022; Reusswig, 2022).

Infectious diseases and zoonoses

The outbreak of a pandemic is not random but driven by the same environmental disruptions underlying the triple planetary crisis which collectively increase the risk of future outbreaks. The COVID-19 pandemic has illustrated how ecosystem disturbance, biodiversity loss, and intensified human-wildlife contact facilitate zoonotic spillover. Over 70 % of emerging diseases, and almost all pandemics originate in microbes of animal origin, often linked to intensified human-wildlife contact due to environmental disruption (Daszak et al., 2020; Reusswig, 2022). For instance, in tropical regions with rapid land-use change and high mammalian biodiversity, vulnerable communities face increased risk of zoonotic disease spillover due to intensified human–wildlife contact (Destoumieux-Garzón et al., 2022).

Climate change further amplifies these risks, expanding the geographic range and activity of vectors such as mosquitoes and ticks, increasing the incidence of vector-borne diseases like dengue, malaria, West Nile virus, and Lyme disease. More frequent and intense extreme weather events, as well as rising temperatures, also contribute to the spread of water- and food-borne illnesses and worsen air quality, aggravating respiratory and cardiovascular conditions (IPCC, 2022). In addition to physical health threats, these climate-driven changes increase the risk of psychological stress, anxiety, and trauma, both as a result of acute events such as disasters and through the ongoing awareness of environmental instability (Hertig et al., 2023).

Systemic and indirect impacts

The triple planetary crisis gives rise to wide-ranging systemic and indirect effects that fundamentally threaten food security, livelihoods, and human development.

Persistent plastics and plastic-associated chemicals undermine the production, availability, and safety of food systems worldwide (Yates et al., 2025). Micro- and nanoplastics, together with their additives, have been shown to interact with other environmental contaminants such as heavy metals and antibiotics, amplifying toxicity and systemic risks for both ecosystems and human populations (Essien et al., 2025). These interactions further increase the risks of chronic and multifactorial diseases in humans (Destoumieux-Garzón et al., 2022).

Chemical pollution also accelerates the evolution of pathogens, as substances such as antibiotics and heavy metals select for resistant bacteria and promote the emergence of more resilient pathogens. Such pollutants can increase human vulnerability by triggering immune toxicity and altering immune-epigenetic responses, thereby raising the risk of infectious diseases (Destoumieux-Garzón et al., 2022). As climate change and pollution further erode ecosystem services, health risks and systemic vulnerabilities deepen. Across regions, individuals' opportunities and capacities for development are increasingly determined by their environmental context. Increasingly, water and food insecurity are forcing people to leave uninhabitable areas, leading to conflict and displacement (Drenckhahn et al., 2020).

The health impacts of the triple planetary crisis fall disproportionately on marginalized and vulnerable communities. Regional and socio-economic disparities in exposure to pollution, climate hazards, and ecosystem degradation translate into disproportionate risks of disease, malnutrition, and reduced life expectancy. Communities with limited access to healthcare, information, or basic infrastructure are more vulnerable to health crises arising from environmental hazards. These health inequities are compounded by systemic factors such as poor public health preparedness, under-resourced medical systems, and historic patterns of marginalization (Drenckhahn et al., 2020; Wittmer et al., 2021). Factors such as gender, ethnicity, low income, informal settlements, disability, age, and the enduring effects of historical and ongoing inequities, including colonialism, especially among Indigenous Peoples and local communities (UNEP, 2006), further exacerbate vulnerability (IPCC, 2023b).

5 Socioeconomic impacts of the triple planetary crisis & the MAPA perspective

Mapping vulnerability in the triple planetary crisis: a MAPA-based analysis of scientific discourse

As described previously, the converging crises of climate change, biodiversity loss, and pollution pose complex and interconnected threats to planetary health and social stability. Within this context, identifying the Most Affected People and Areas (MAPA) is crucial to ensure that governance responses prioritize those disproportionately impacted. The term MAPA encompasses both demographic groups (e.g., Indigenous Peoples, women, people in poverty) and geographic regions (e.g., small island developing states, low-lying coastal zones, arid regions) that face heightened vulnerability due to structural inequalities and historical marginalization. During the literature search, the MAPA perspective was not one of the search criteria. Hence the following analysis applies the MAPA perspective to the sources that were already collected based on other search criteria.[3]

The following search terms related to the MAPA categories were used:

Groups

- Indigenous Peoples & local communities
- People in poverty
- Women and gender
- Disabled persons
- Youth
- Racialized communities
- Urban informal settlements

Regions

- Arid/semi-arid regions
- Coastal/low-lying areas
- Small island developing states (SIDS)
- Global South
- Arctic regions

Among the MAPA categories focusing on certain groups, Indigenous Peoples were the most frequently mentioned demographic group, appearing in five separate texts (Chungyalpa et al., 2025; ECHOES et al., 2024; IPBES, 2024b, 2024a; IPCC, 2023b; Miao and Nduneseokwu, 2024). These studies commonly highlight the dual role of Indigenous Peoples as particularly vulnerable to environmental degradation and as holders of valuable knowledge for sustainable governance. For instance, IPCC (2023a) stresses the importance of indigenous knowledge systems for biodiversity preservation, while ECHOES (2024) underscores the disproportionate exposure of indigenous communities to environmental harms due to historical marginalization and land dispossession.

In contrast, all the other MAPA groups were underrepresented. While IPBES (2024b) mentions all the MAPA groups, Hellin et al. (2023) as well as IPCC (2023a) mention marginalized groups in general. Regarding MAPA regions, only arid regions (Sharma et al., 2025), coastal regions (Halpe et al., 2025) and SIDS (ECHOES et al., 2024) were mentions to a certain extent, in addition to the Global South in general (Brosig, 2025; Chungyalpa et al., 2025; ECHOES et al., 2024; Hellin et al., 2023).

[3] For a description on the methodology used, see Appendix 1.

References to climate change were the most common context in which MAPA groups appeared. For example, IPCC (2023b) highlights how the most vulnerable groups face heightened exposure and reduced adaptive capacity due to gendered, and spatial inequalities (a term referring to how the places where people live drive uneven distribution of resources, services, and opportunities). The role of Indigenous Peoples in climate resilience is emphasized in Miao & Nduneseokwu (2024) which argues that integrating traditional knowledge into local adaptation planning enhances both legitimacy and effectiveness.

Biodiversity-related publications feature Indigenous Peoples prominently. IPBES (2024b) underscores how indigenous land stewardship correlates with higher biodiversity outcomes and calls for the decolonization of conservation science. However, beyond these references, few studies examine how other MAPA groups experience or influence biodiversity governance. The lack of intersectional analysis (e.g., gender and biodiversity, or poverty and ecosystem access) is a notable limitation in the current literature sample.

The topic of pollution receives the least attention in relation to MAPA. Despite growing evidence that marginalized communities often reside in proximity to pollution sources, this connection is scarcely made in the sampled literature. No article explicitly mentions the disproportionate burden of air or chemical pollution on racialized or low-income communities - an omission that reflects a broader trend in the environmental sciences toward technocratic framings of pollution, detached from social justice concerns.

This analysis reveals a significant disparity in the visibility of different MAPA groups. While Indigenous Peoples are relatively well-represented, other groups - including youth, racialized communities, and small island nations—are almost invisible in the reviewed texts. This disparity raises questions about whose vulnerability is deemed relevant or worthy of scholarly attention. Several factors are likely to contribute to these gaps. First, the positionality of researchers, often situated in institutions of the Global North, may shape the framing of environmental risks (ECHOES et al., 2024; GSDR, 2023). Second, data limitations and disciplinary silos can marginalize social perspectives in climate, biodiversity, and pollution research (Miao and Nduneseokwu, 2024; UNEP, 2024). Finally, the politics of funding and publication may incentivize framings of problems that align with institutional priorities rather than local realities (IPBES, 2024b).

The analytical perspective used in this analysis highlights both the presence and the absence of MAPA groups in the literature analyzed. While some attention is paid to Indigenous Peoples and, to a lesser extent, to poor populations and people of all genders, entire communities central to global justice movements are only marginally considered (e.g. youth, disabled persons, Racialized communities, people living in urban informal settlements and other marginalized people like illegal persons and waste pickers). This gap is particularly striking given the centrality of these groups in international climate justice discourse. Future research must commit to making MAPA visible, not merely as objects of concern but as agents of transformative change (see also Burgos Cuevas et al., 2025).

Transformative leverage points across sectors

Addressing the triple planetary crisis of climate change, biodiversity loss, and pollution requires the activation of transformative leverage points across key sectors. A review of recent sectoral strategies reveals promising approaches that not only respond to the symptoms of the triple planetary crisis but also tackle underlying systemic and institutional barriers (see also Iwaszuk et al., 2025).

One such leverage point lies in the **circular economy** (CE). At the macroeconomic scale, a circular economy seeks to break the link between economic growth and the consumption of natural resources (decoupling). In principle, resource extraction should stay below the level of resource use, while waste generation should not exceed the environment's capacity to absorb and process it. A circular economy functions as a regenerative system, aiming to minimize resource inputs as well as waste, emissions, and energy losses by promoting durable design, regular maintenance, repair, reuse, sharing, remanufacturing, refurbishment, and recycling (UNEN, 2021). This is particularly important for plastic pollution, since there is a direct link between the amount of pollution and the amount of primary plastic polymers produced. An increase in plastic production goes hand in hand with an increase in plastic waste (Cowger et al., 2024; Geyer, 2020; Scientist's Coalition for an Effective Plastics Treaty, 2024).

However, different actors along the value chain are still not working together sufficiently to unlock the full potential of a circular economy with regard to all the material flows. Panza et al. (2023) highlight that "*the effective implementation of a CE requires an efficient information flow between several actors of the value chain*," and propose the Digital Product Passport (DPP) as a key tool in this regard. According to the authors, the DPP "*is regarded as a prominent tool to promote environmental and social sustainability*" (p. 3). Importantly, circularity is not just a matter of technical efficiency; it also poses deep governance and institutional challenges that must be addressed to unlock its full transformative potential.

In the domain of **water governance**, the potential for co-benefits across ecological, social, and climate dimensions is also significant. He and James (2021), for instance, argue for a rethinking of how ecosystem services are integrated into water-management decisions: *"Ecosystem-service analysis should define the amount of ecologic benefits that would be produced by allocating and delivering more water for enhancing ecosystem services each year […], particularly those intangible services such as soil conservation, desertification control, reduction of sandstorms, flood management, watershed protection, habitat provision, water and air quality improvement"* (p. 681). This broadened perspective reframes water allocation not merely as a resource issue but as a driver of multiple, interconnected ecosystem functions.

Further building on cross-sectoral integration, Quagliarotti (2023) emphasizes the importance of transforming the conventional **Water-Energy-Food (WEF) nexus** into a more resilient and adaptive framework. She argues that *"new global systemic risks call for a paradigm shift by adopting measures to reduce exposure and strengthen resilience,"* and identifies three key actions: *"mainstreaming climate change into the WEF nexus; decoupling water, energy and food production from fossil fuel; and developing sustainable WEF intra-regional and regional cooperation/ integration models based on the principle of comparative advantages"* (p. 7). This illustrates how sectoral interdependencies, when properly understood and managed, can become engines of resilience rather than amplifiers of risk.

Economic and social consequences of the Triple Planetary Crisis

The triple planetary crisis poses not only environmental but also profound economic and societal risks. Human societies and economies are fundamentally dependent on the Earth system, which provides essentials such as food, water, energy, and raw materials (Trust et al., 2025). Disruptions to these systems cascade through economies, producing losses that are both immediate and long-term. For example, deforestation reduces crop yields and drought resilience, costing the world an estimated US-$379 billion annually, while deforestation-driven rainfall loss alone limits economic growth in Amazonian countries by US-$14 billion per year (Damania et al., 2025). Excess nitrogen from fertilizers imposes global costs of up to US-$3.4 trillion annually, while air pollution, responsible for at least 5.7 million deaths each year, diminishes labour productivity and gross domestic product (GDP) growth through illness and reduced cognitive function (Damania et al., 2025; WEF, 2025).

Furthermore, heat, extreme heat, and heat waves affect human health and well-being. The European Environment Agency (EEA) describes heat as "the largest and most urgent climate hazard for human health" (EEA, 2024). A 2025 study found that summer heat deaths had more than tripled in 854 European cities due to climate change (Barnes et al., 2025). This again has cost implications for health infrastructure and labour productivity. Usman et al. (2025) estimate that floods, droughts, and heatwaves across Europe in summer 2025 will reduce economic output in the affected regions by about €43 billion - around 0.26% of total EU GDP. The damage will not stop there: based on past patterns, the lasting effects mean that by 2029 annual output in these regions could be €126 billion lower than if the events had not happened. According to a study by scientists at the Potsdam Institute for Climate Impact Research (PIK), climate change is estimated to reduce global income by 19% by 2050. This estimate reflects damages caused by past emissions alone, meaning that even drastic future emission reductions cannot undo these losses. The economic damages already locked in are about six times higher than the costs of limiting global warming to two degrees, as set out in the Paris Agreement (Kotz et al., 2024). The largest committed climate-related income losses are concentrated in low-latitude, low-income countries with relatively small historical emissions, making the impacts highly unequal and unjust. South Asia and Sub-Saharan Africa are the regions facing the steepest projected income reductions of about 22%, despite being least responsible for climate change and having the fewest resources to adapt (Kotz et al., 2024).

As mentioned in Chapter 4, PFAS has health impacts. Eliminating the most concentrated sources of long-chain PFAS (i.e. PFOS, PFOA, PFNA, PFHxS) in Europe would require an annual investment of €4.8 billion, even if PFAS use were to cease immediately. If emissions continue, expenses will rise sharply. Eliminating all PFAS would be far more costly. The Forever Pollution Project calculated that removing short-chain and ultrashort-chain PFAS from the environment and destroying them would cost around €100 billion every year, even partially. That's more than two trillion euros over 20 years. These costs are typically borne by society, though in rare cases, such as when strict regulations require it, polluters may be held responsible.[4]

Furthermore, Trasande et al. (2024) estimated that in 2018 alone, endocrine-disrupting chemicals used in plastics led to approximately US $250 billion in additional health care costs in the United States. In a separate analysis, Cropper et al. (2024) examined the economic impacts of

[4] See Unaffordable - The absurd cost of 'PFAS as usual', URL https://foreverpollution.eu/lobbying/the-cost-of-remediation/, retrieved 18 Sep. 25.

inadequate regulation of hazardous plastic-related chemicals across 38 countries representing one-third of the global population. Their findings suggest that up to US $1.5 trillion in societal costs - stemming from premature deaths and reductions in IQ - could have been avoided if the regulatory standards in place in 2015 had already been implemented back in 2003. If the full environmental and health costs were reflected in the price of (plastic) products, current levels of consumption would no longer be economically viable (Syberg et al., 2025).

Food systems are particularly vulnerable to systemic environmental shocks. Synchronous failures of multiple breadbaskets due to extreme weather events, collapse of critical climate systems such as the Atlantic Meridional Overturning Circulation (AMOC), or disruptions in agricultural inputs could reduce staple crop production by up to 40%, triggering global famine and severe socio-economic instability (Wescombe et al., 2025). Similarly, inadequate waste management and pollution could double annual global costs from $361 billion to $640 billion by 2050, disproportionately affecting low- and middle-income countries (WEF, 2025).

The social ramifications of these crises are equally severe. Widespread environmental disruptions are likely to drive involuntary mass migration, heat- and water-related stress, disease outbreaks, and socio-political fragmentation, with catastrophic mortality scenarios exceeding two billion people under high-emission pathways (Trust et al., 2025). Economic inequality amplifies vulnerability, as the poorest populations bear the heaviest burden of resource scarcity, health impacts, and exposure to environmental hazards.

Taken together, these interlinked crises undermine the very foundations of modern economies. Attempting to calculate conventional economic costs is of limited sensibility and often wrong: Current environmental risk assessment methods tend to underestimate economic impacts because they frequently omit some of the most severe anticipated risks and fail to account for the possibility of catastrophic systemic collapse. Rather than providing approximate estimates, these approaches can be fundamentally misleading. Unchecked, the triple planetary crisis could produce societal conditions fundamentally unlike today's system, where GDP or market-based metrics are largely irrelevant and conflict, resource scarcity, and societal collapse dominate. The economic and social stakes of environmental degradation thus extend far beyond standard accounting frameworks, highlighting the urgency of systemic interventions to safeguard both human wellbeing and planetary stability.

Disproportionate and unequal burdens

A critical dimension of systemic transformation is recognizing how the burdens of the triple planetary crisis are unevenly distributed across populations and geographies. Wittmer et al. (2021) stress that there are massive social inequalities, both within and between regions, underscoring that the social costs of environmental degradation are not borne equally. Similarly, Drenckhahn et al. (2020) emphasize that people are affected very differently in terms of their life chances and development opportunities depending on the region, pointing to stark disparities in how environmental change constrains human development potential.

Corbane et al. (2024) add a further layer of complexity by highlighting how infrastructural and institutional vulnerabilities intersect with geographic vulnerabilities*: "A lack of awareness of the risks, inadequate control measures, poor maintenance, ageing infrastructure, lack of preparedness [...] can add significantly to the risk of a serious accident originating in an activity already in a vulnerable location relative to cross-boundary industrial risk"* (p. 61). This illustrates the compounding nature of vulnerability—how environmental risks become crises when layered atop systemic neglect and inequality, a dynamic that applies not just to industrial risks but also to climate-, biodiversity- and pollution-related risks generally, all of which can have profoundly different impacts as a function of how particular vulnerability types intersect.

Scheffran (2023) offers a more systemic reading of how climate change interacts with overlapping stressors to create destabilizing dynamics in human security. He argues that climate change is part of a complex pattern of overlapping stressors on human security; this pattern acts as a risk amplifier in fragile hot spots and links ecological and social instabilities and tipping points. While the immediate impacts may initially be local or sectoral, they can spread in a globally interconnected world via teleconnections and, through chains of events, escalate into complex crises, global cascades and geopolitical tensions that are difficult to control. He points to examples such as communication and transport systems, social networks and media, supply chains, energy grids, disease spread, environmental change, trade systems, and migration flows as domains where teleconnected crises manifest and cascade.

These insights underscore the urgent need for anticipatory and equity-centered governance. Transformative change is not only about shifting technologies or redesigning systems—it also requires a deep understanding of who is affected, how, and why. Only by embedding distributive justice and systemic awareness into sectoral strategies can we hope to navigate the complexities of the polycrisis effectively.

6 Synthesis and Outlook

The triple planetary crisis, encompassing climate change, biodiversity loss, and pollution, has evolved into an interconnected system of risks and feedback that now shapes the boundaries of planetary and human health. This analysis has shown that the crisis is fundamentally driven by anthropogenic activities through fossil-fuel dependency, unsustainable production and consumption, land and resource exploitation, and entrenched social and economic inequalities. These drivers do not operate in isolation but reinforce each other through feedback loops that accelerate ecological destabilization and deepen social vulnerabilities.

The consequences of transgressing planetary boundaries are profound and far-reaching. Climate change, along with the degradation of soil quality, contamination by chemical substances and plastics, and the decline of biodiversity, erode the resilience of ecosystems worldwide. Rising temperatures lead to shifting rainfall patterns, an increased frequency of extreme weather events, and rising sea levels. The resulting disruption of nutrient cycling, water regulation, and carbon sequestration in soils undermine the foundation for water and food security and livelihoods. At the same time, the triple planetary crisis increases direct health risks for human populations, from chronic disease linked to chemical exposures to the emergence of new infectious diseases and pandemics through ecological disruption and increased human-wildlife contact. The crisis also exerts a growing toll on mental health, as people confront loss of livelihoods, instability, and escalating environmental stressors.

A critical insight from this analysis is that the impacts of the triple planetary crisis are highly unequal. When viewed from a MAPA (Most Affected People and Areas) perspective, it becomes evident that marginalized populations, namely Indigenous Peoples, women, people in poverty, residents of informal settlements, and others central to global justice debates including youth, racialized communities, and the Global South bear a disproportionate share of harm, often while being underrepresented or overlooked in both research and policy. Crucially, those who are most affected have typically contributed least to the root causes of the crisis.

The triple planetary crisis is driving massive economic losses by undermining food production, reducing labour productivity, damaging health, and increasing infrastructure costs. Global income is projected to fall by 19% by mid-century due to past emissions alone, with South Asia and Sub-Saharan Africa facing the steepest reductions despite their low historical responsibility. Pollution further adds trillions in annual health costs, while plastic- and chemical-related damages highlight the hidden liabilities of current production systems.

The consequences of the triple planetary crisis are now reverberating far beyond local and national boundaries, increasingly fuelling global geopolitical tensions and cascading systemic risks. Climate change, biodiversity loss, and pollution have increased competition for critical natural resources, heightening tensions, such as in the Arctic, where the loss of sea ice and permafrost is opening new shipping routes, unlocking access to oil and gas reserves, and shifting fisheries. These developments threat the livelihood and cultural identity of Indigenous Peoples in the region (IPCC, 2023b). These environmental pressures not only drive localized conflict but can escalate into humanitarian emergencies and cross-border migration.

The convergence of these environmental and geopolitical shocks - with climate change, pandemic disruption, and war reinforcing each other’s impacts - demonstrates what experts now refer to as a true “polycrisis”: a situation where multiple, overlapping crises interact in ways that are significant in scope, devastating in effect, and difficult to anticipate or manage with conventional tools (Quagliarotti, 2023). The triple planetary crisis both drives and amplifies our present polycrisis, suffering from feedback effects that the additional crises have had on society's ability and willingness to address global environmental issues. Developing integrated and anticipatory responses has become even more urgent as the political complexity of responding to these crises has grown.

The war in Ukraine starkly illustrates the entanglement of geopolitical and environmental crises. The conflict has disrupted global energy and food supply chains, underscoring the vulnerability created by fossil fuel dependency and unsustainable resource use - key drivers of the triple planetary crisis. Its impacts are particularly striking in 'climate change hotspots', such as in the Mediterranean, where the intersection of the crises threaten water, energy and food access (Quagliarotti, 2023). Rising energy prices have in some regions triggered a shift back to coal or other polluting fuels, slowing climate action and increasing greenhouse gas emissions. Fertilizer shortages and agricultural disruptions have intensified food insecurity, particularly in regions already threatened by climate extremes and ecosystem decline. Moreover, the war has exacerbated pollution and environmental destruction locally, adding to the burdens faced by populations already vulnerable to the impacts of the triple planetary crisis.

As awareness of the triple planetary crisis gains traction in global policy arenas - from the UNFCCC's Global Stocktake to the post-2020 Global Biodiversity Framework - there remains a risk that marginalized voices and perspectives are excluded from scientific literature and policymaking. This could have material consequences, risking the reproduction of the very injustices these interventions seek to address. Embedding MAPA criteria and differentiated vulnerability into international reporting and decision-making processes - such as Nationally Determined Contributions (NDCs), Global Environment Outlooks, and treaty negotiations on plastics and chemicals - is therefore essential to ensure a truly just transition.

Cross-sectoral innovations, such as circular economy tools, sustainable water and food governance, the deployment of renewable energy systems and green and blue infrastructure, are essential levers for addressing the systemic threats posed by the triple planetary crisis. Their transformative potential lies in their ability to address the root causes of the systemic crises and to bridge the divides between sectors, creating synergetic solutions across food, energy, water, and waste systems. Yet, the long-term effectiveness of these measures relies on embedding them within justice-oriented governance frameworks that ensure access, participation, and agency for those most affected. Only by systematically integrating differentiated vulnerabilities and local and Indigenous knowledge into governance and planning can policies realize the full benefits of cross-sectoral innovations and avoid reinforcing existing inequalities. At the same time, these sectoral measures must also be designed to address the deeply interconnected threats to ecosystem health posed by the triple planetary crisis. Because the triple planetary crisis operates through feedback loops aggravating its impacts, truly effective interventions need to strengthen the resilience of natural systems alongside social systems. Without a systemic approach that recognizes and responds to these ecological dependencies and cross-sectoral risks, piecemeal solutions may inadvertently undermine both human and ecosystem resilience.

Together, these insights point to several overarching lessons for research, policy, and practice. The following key findings synthesize the core messages of this report and highlight the priorities that must guide future action:

- **The triple planetary crisis requires systemic, integrated and cross-sectoral responses:** Climate change, biodiversity loss, and pollution interact and reinforce each other, so siloed approaches risk inefficiency and unintended negative consequences. Cross-sectoral coordination and anticipatory governance are crucial to address the complexity of these interconnections, capable of adapting to emerging risks and shocks
- **Impacts and vulnerabilities are deeply unequal and layered:** Vulnerabilities are compounded by social, economic, and institutional inequities, with the greatest burdens borne by those least equipped to respond or recover. Policy blind spots persist when these groups are not adequately included in research and governance.
- **Equity and justice must guide solutions:** Technological, sectoral, and policy innovations must be explicitly aligned with distributive justice and inclusion; otherwise, they risk reinforcing marginalization and losing legitimacy and effectiveness.
- **Integrated responses must be managed well:** While integration is essential, excessive complexity can hinder political and practical implementation. The most effective responses are those that remain understandable, garner political support, and are feasible to implement at reasonable cost.

Meeting the challenges of the triple planetary crisis will require not only the ability to see the ways that the climate, biodiversity and pollution crises interrelate. Also, urgently needed are new policy approaches and governing frameworks (the toolbox) that can harness the resulting insights while avoiding unmanageable complexities. Successful approaches to addressing the triple planetary crisis will strike this balance to find political resonance, deliver technical innovation, foster cross-sectoral collaboration, and deliver justice, inclusion, resilience and long-term wellbeing for human society.

7 List of references

Bachmann, M., Zibunas, C., Hartmann, J., Tulus, V., Suh, S., Guillén-Gosálbez, G., and Bardow, A. (2023). Towards circular plastics within planetary boundaries. *Nature Sustainability*, *6*(5), 599–610. https://doi.org/10.1038/s41893-022-01054-9

Barnes, C., Konstantinoudis, G., Masselot, P., Mistry, M., Gasparrini, A., Vicedo-Cabrera, A. M., Theokritoff, E., Clarke, B., and Otto, F. (2025). *Summer heat deaths in 854 European cities more than tripled due to climate change*. https://doi.org/10.25560/123873

Berti, G. (2020). Sustainable Agri-Food Economies: Re-Territorialising Farming Practices, Markets, Supply Chains, and Policies. *Agriculture*, *10*(3), 64. https://doi.org/10.3390/agriculture10030064

Briassoulis, D. (2023). Agricultural plastics as a potential threat to food security, health, and environment through soil pollution by microplastics: Problem definition. *Science of The Total Environment*, *892*, 164533. https://doi.org/10.1016/j.scitotenv.2023.164533

Brocchi, D. (2024). *By Disaster or by Design? Transformative Kulturpolitik: Von der Polykrise zur systemischen Nachhaltigkeit*. Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-42317-9_3

Brosig, M. (2025). Nun aber wirklich mehr Einfluss auf die Weltpolitik: BRICS+ im Zeitalter der Polykrise. *Zeitschrift für Außen- und Sicherheitspolitik*, *18*(1), 145–163. https://doi.org/10.1007/s12399-025-01024-x

Bucksch, J., and Schlicht, W. (2023). Umwelt und Gesundheit: Die Folgen des reziproken Determinismus. In J. Bucksch and W. Schlicht, *Kommunale Gesundheitsförderung* (pp. 73–104). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-662-67720-9_4

Bunsen, J., Berger, M., and Finkbeiner, M. (2021). Planetary boundaries for water – A review. *Ecological Indicators*, *121*, 107022. https://doi.org/10.1016/j.ecolind.2020.107022

Burgos Cuevas, N., Heni, Y., Spantzel, T., Felthöfer, C., Brunkhorst, H., Knoblauch, D., and Riedel, A. (2025). *Moving from Interconnected Crises to Systemic Solutions—Resource Efficiency, Nature-based Solutions, and Systemic Transformation as Responses to the Complexity of the Triple Planetary Crisis*. German Environment Agency. https://doi.org/10.60810/openumwelt-8108

Carney Almroth, B., and Villarrubia-Gómez, P. (2024). *Plastics and the Triple Planetary Crisis*. https://doi.org/10.5281/ZENODO.10880588

Carroll, C., Noss, R. F., Dreiss, L. M., Hamilton, H., and Stein, B. A. (2023). Four challenges to an effective national nature assessment. *Conservation Biology*, *37*(5), e14075. https://doi.org/10.1111/cobi.14075

Casonato, C., Sanyé-Mengual, E., Vittuari, M., and Sala, S. (2024). Life cycle assessment to support public procurement of food: A review. *Cleaner Environmental Systems*, *15*, 100239. https://doi.org/10.1016/j.cesys.2024.100239

Chungyalpa, D., Gauthier, P. E., Goldman, R. I., Vikas, M., and Wilson-Mendenhall, C. D. (2025). A Framework for Deep Resilience in the Anthropocene. *Humanistic Management Journal*, *10*(1), 49–64. https://doi.org/10.1007/s41463-024-00195-7

Corbane, C., Eklund, G., Gyenes, Z., and Lentini, A. (2024). *Cross-border and emerging risks in Europe: Overview of state of science, knowledge and capacity.* (European Commission. Joint Research Centre., Ed.). Publications Office. https://data.europa.eu/doi/10.2760/184302

Cowger, W., Willis, K. A., Bullock, S., Conlon, K., Emmanuel, J., Erdle, L. M., Eriksen, M., Farrelly, T. A., Hardesty, B. D., Kerge, K., Li, N., Li, Y., Liebman, A., Tangri, N., Thiel, M., Villarrubia-Gómez, P., Walker, T. R., and Wang, M. (2024). Global producer responsibility for plastic pollution. *Science Advances*, *10*(17), eadj8275. https://doi.org/10.1126/sciadv.adj8275

Cozzolino, M., Salomone, R., Ricca, B., and Gulotta, T. M. (2025). Circular economy in aquaculture: An Italian survey to understand perceptions, challenges and options for transition. *Marine Policy*, *176*, 106660. https://doi.org/10.1016/j.marpol.2025.106660

Cropper, M., Dunlop, S., Hinshaw, H., Landrigan, P., Park, Y., and Symeonides, C. (2024). The benefits of removing toxic chemicals from plastics. *Proceedings of the National Academy of Sciences*, *121*(52), e2412714121. https://doi.org/10.1073/pnas.2412714121

Damania, R., Ebadi, E., Mayr, K., Russ, J., and Zaveri, E. (2025). *Reboot Development: The Economics of a Livable Planet*. World Bank, Washington, DC. https://doi.org/10.1596/978-1-4648-2271-1

Daszak, P., Amuasi, J., das Neves, C. G., Hayman, D., Kuiken, T., Roche, B., Zambrana-Torrelio, C., Buss, P., Dundarova, H., Feferholtz, Y., Foldvari, G., Igbinosa, E., Junglen, S., Liu, Q., Suzan, G., Uhart, M., Wannous, C., Woolaston, K., Mosig Reidl, P., … Ngo, H. T. (2020). *Workshop Report on Biodiversity and Pandemics of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES)* (Version 1.4). Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES). https://doi.org/10.5281/ZENODO.4147317

Dehghani, M. H., Aghaei, M., Bashardoust, P., Rezvani Ghalhari, M., Nayeri, D., Malekpoor, M., Sheikhi, S., and Shi, Z. (2025). An insight into the environmental and human health impacts of per- and polyfluoroalkyl substances (PFAS): Exploring exposure pathways and their implications. *Environmental Sciences Europe*, *37*(1), 81. https://doi.org/10.1186/s12302-025-01122-9

Destoumieux-Garzón, D., Matthies-Wiesler, F., Bierne, N., Binot, A., Boissier, J., Devouge, A., Garric, J., Gruetzmacher, K., Grunau, C., Guégan, J.-F., Hurtrez-Boussès, S., Huss, A., Morand, S., Palmer, C., Sarigiannis, D., Vermeulen, R., and Barouki, R. (2022). Getting out of crises: Environmental, social-ecological and evolutionary research is needed to avoid future risks of pandemics. *Environment International*, *158*, 106915. https://doi.org/10.1016/j.envint.2021.106915

Diller, C. (2024). Polykrisen: Beschleuniger oder Bremser von räumlichen Transformationsprozessen? *disP - The Planning Review*, *60*(3), 80–88. https://doi.org/10.1080/02513625.2024.2471171

Drenckhahn, D., Arneth, A., Filser, J., Haberl, H., Hansjürgens, B., Herrmann, B., Homeier, J., Leuschner, C., Mosbrugger, V., Reusch, T. B. H., Schäffer, A., Scherer-Lorenzen, M., and Tockner, K. (2020). *Globale Biodiversität in der Krise: Was können Deutschland und die EU dagegen tun? = Global biodiversity in crisis: what can Germany and the EU do about it?* (H. Steinicke, Ed.). Deutsche Akademie der Naturforscher Leopoldina e.V. - Nationale Akademie der Wissenschaften.

ECHOES, Zuccarelli Freire, V., Ziegler, M. J., Caetano-Andrade, V., Iminjili, V., Lellau, R., Stokes, F., Rudd, R. C., Heberle Viegas, D., Maezumi, S. Y., Jha, G., Antonosyan, M., Jha, D. K., Winkelmann, R., Roberts, P., Furquim, L., and ECHOES. (2024). Addressing the Anthropocene from the Global South: Integrating paleoecology, archaeology and traditional knowledge for COP engagement. *Frontiers in Earth Science*, *12*, 1470577. https://doi.org/10.3389/feart.2024.1470577

EDGAR. (2024). *GHG emissions of all world countries* (JRC/IEA Report). European Commission. https://doi.org/10.2760/4002897

EEA. (2024). *European climate risk assessment: Executive summary*. Publications Office of the European Union. https://doi.org/10.2800/204249

Ellwanger, J. H., and Bogo Chies, J. A. (2025). Triple planetary crisis and emerging zoonotic diseases: Consider degrowth as a solution. *Earth Critical Zone*, 100030. https://doi.org/10.1016/j.ecz.2025.100030

Essien, A. E., Dickson-Anderson, S. E., and Guo, Y. (2025). Utilizing nature-based adsorbents for removal of microplastics and nanoplastics in controlled polluted aqueous systems: A systematic review of sources, properties, adsorption characteristics, and performance. *Next Sustainability*, *5*, 100119. https://doi.org/10.1016/j.nxsust.2025.100119

Fady, P.-E., Richardson, A. K., Barron, L. P., Mason, A. J., Volpe, R., and Barr, M. R. (2025). Biochar filtration of drug-resistant bacteria and active pharmaceutical ingredients to combat antimicrobial resistance. *Scientific Reports*, *15*(1), 1256. https://doi.org/10.1038/s41598-024-83825-2

Felthöfer, C., Knoblauch, D., and Best, A. (2025). *Factsheet: The Interconnected Challenges of Climate Change, Biodiversity Loss and Environmental Pollution—Drivers, Interdependencies and Impacts of the Triple Planetary Crisis*. German Environment Agency. https://doi.org/10.60810/openumwelt-8070

Ferraz, D., and Barreira, D. (2024). Preparing for future pandemics while responding to the current ones in the midst of a planetary climate crisis: Can we face this triple global health challenge? *Global Public Health*, *19*(1), 2351593. https://doi.org/10.1080/17441692.2024.2351593

Fisher, J., Splieth, C., Matanhire-Zihanzu, C., and Glick, M. (2024). Advancing the concept of global oral health to strengthen actions for planetary health and One Health. *International Journal for Equity in Health*, *23*(1), 71. https://doi.org/10.1186/s12939-024-02176-6

Frey, F. P., Krahl Perez, C., and Schliep, R. (2023). Resilienz der Biosphäre. In V. Wittpahl (Ed.), *Resilienz* (pp. 28–46). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-662-66057-7_2

Geyer, R. (2020). Production, use, and fate of synthetic polymers. In *Plastic Waste and Recycling* (pp. 13–32). Elsevier. https://doi.org/10.1016/B978-0-12-817880-5.00002-5

Ghani, H. U., Mahmood, A., Finkbeiner, M., Kaltschmitt, M., and Gheewala, S. H. (2023). Evaluating the absolute eco-efficiency of food products: A case study of rice in Pakistan. *Environmental Impact Assessment Review*, *101*, 107119. https://doi.org/10.1016/j.eiar.2023.107119

GSDR. (2023). *Global Sustainable Development Report 2023*. United Nationas Department of Economic and Social Affairs. https://sdgs.un.org/gsdr/gsdr2023

Haderer, M., Brand, U., Daniel, A., Exner, A., Fankhauser, J., Görg, C., Novy, A., Schinko, T., Schlitz, N., and Strüver, A. (2023). Kapitel 28. Theorien des Wandels und der Gestaltung von Strukturen: Gesellschaft-Natur-Perspektive. In C. Görg, V. Madner, A. Muhar, A. Novy, A. Posch, K. W. Steininger, and E. Aigner (Eds.), *APCC Special Report: Strukturen für ein klimafreundliches Leben* (pp. 691–715). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-662-66497-1_32

Halpe, P., Adams, M., and Walker, T. R. (2025). Challenges and opportunities for ports in achieving net-zero emissions in maritime transport. *Transportation Research Interdisciplinary Perspectives*, *30*, 101379. https://doi.org/10.1016/j.trip.2025.101379

Hansen, R., Enderich, L., and Davis, M. (2024). *Stadtnatur-Plan: Lebensqualität, Klima und biologische Vielfalt zusammendenken!* Bundesamt für Naturschutz. https://doi.org/10.19217/brs241

Hartley, K., Baldassarre, B., and Kirchherr, J. (2024). Circular economy as crisis response: A primer. *Journal of Cleaner Production*, *434*, 140140. https://doi.org/10.1016/j.jclepro.2023.140140

He, C., and James, L. A. (2021). Watershed science: Linking hydrological science with sustainable management of river basins. *Science China Earth Sciences*, *64*(5), 677–690. https://doi.org/10.1007/s11430-020-9723-4

Hege, E. (2025). *Are the key innovations of the Paris Climate Agreement and the 2030 Agenda weathering the multilateral crisis?* IDDRI. https://www.iddri.org/en/publications-and-events/study/are-key-innovations-paris-climate-agreement-and-2030-agenda

Hellin, J., Fisher, E., Taylor, M., Bhasme, S., and Loboguerrero, A. M. (2023). Transformative adaptation: From climate-smart to climate-resilient agriculture. *CABI Agriculture and Bioscience*, *4*(1), 30. https://doi.org/10.1186/s43170-023-00172-4

Hellweg, S., Benetto, E., Huijbregts, M. A. J., Verones, F., and Wood, R. (2023). Life-cycle assessment to guide solutions for the triple planetary crisis. *Nature Reviews Earth & Environment*, *4*(7), 471–486. https://doi.org/10.1038/s43017-023-00449-2

Hertig, E., Hunger, I., Kaspar-Ott, I., Matzarakis, A., Niemann, H., Schulte-Droesch, L., and Voss, M. (2023). *Klimawandel und Public Health in Deutschland—Eine Einführung in den Sachstandsbericht Klimawandel und Gesundheit 2023*. https://doi.org/10.25646/11391

Herzog, C., and Kondratjuk, M. (2024). Wissenschaftliche Weiterbildung vor dem Hintergrund sozial-ökologischer Transformation. *Zeitschrift Hochschule und Weiterbildung*, *1*, 21–29. https://doi.org/10.25656/01:30456

Ihsan, F. R., Bloomfield, J. G., and Monrouxe, L. V. (2024). Triple planetary crisis: Why healthcare professionals should care. *Frontiers in Medicine*, *11*, 1465662. https://doi.org/10.3389/fmed.2024.1465662

IPBES (Ed.). (2019). *Global Assessment Report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. https://www.ipbes.net/system/files/2021-06/2020%20IPBES%20GLOBAL%20REPORT%28FIRST%20PART%29_V3_SINGLE.pdf

IPBES. (2024a). *Summary for Policymakers of the Thematic Assessment Report on the Interlinkages among Biodiversity, Water, Food and Health of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.* Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES). https://www.ipbes.net/nexus-assessment

IPBES (Ed.). (2024b). *Summary for Policymakers of the Thematic Assessment Report on the Underlying Causes of Biodiversity Loss and the Determinants of Transformative Change and Options for Achieving the 2050 Vision for Biodiversity of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. https://doi.org/10.5281/zenodo.11382230

IPCC. (2022). *Chapter 7: Health, Wellbeing and the Changing Structure of Communities*. Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/ar6/wg2/chapter/chapter-7/

IPCC. (2023a). *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland.* Intergovernmental Panel on Climate Change (IPCC). https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_LongerReport.pdf

IPCC. (2023b). *Summary for policymakers. In: Climate change 2023: Synthesis report. A report of the Intergovernmental Panel on Climate Change. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Intergovernmental Panel on Climate Change (IPCC).

Iwaszuk, E., Spantzel, T., Kroos, F., and Knoblauch, D. (2025). *Integrated approaches to addressing the triple planetary crisis: Country best practice examples—Lessons learned from Brazil, Colombia, Japan, New Zealand, Panama, Rwanda and Sweden*. German Environment Agency. https://doi.org/10.60810/openumwelt-8106

Karali, N., Khanna, N., and Shah, N. (2024). *Climate Impact of Primary Plastic Production*. https://escholarship.org/uc/item/6cc1g99q

Kimpeleer, S., and Erdmann, L. (2025). *Ability of Politicians to Act—Climate protection in the era of the polycrisis* [Report]. German Environment Agency (Umweltbundesamt). https://www.umweltbundesamt.de/en/publikationen/ability-of-politicians-to-act

Kotz, M., Levermann, A., and Wenz, L. (2024). The economic commitment of climate change. *Nature*, *628*(8008), 551–557. https://doi.org/10.1038/s41586-024-07219-0

Kozban, I., Kopsieker, L., Wulf, S., and Hedden-Dunkhorst, B. (2023). *Strengthening synergies for biodiversity and climate*. Bundesamt für Naturschutz. https://doi.org/10.19217/hgr232en

Kurth, T., Wübbels, G., Meyer zum Felde, A., Zielcke, S., Vaupel, M., Buschle, M., Krüger, J.-A., Kreiser, K., and Trapp, M. (2020). *The Biodiversity Imperative for Business Preserving the Foundations of Our Well-Being*. Naturschutzbund Deutschland e.V. (NABU). https://web-assets.bcg.com/2a/f5/e95293214c29877c11251290ebca/2020-09-the-biodiversity-imperative-for-business-final2-002.pdf

Lan, G., Huang, X., Li, T., Huang, Y., Liao, Y., Zheng, Q., Zhao, Q., Yu, Y., and Lin, J. (2025). Effect of microplastics on carbon, nitrogen and phosphorus cycle in farmland soil: A meta-analysis. *Environmental Pollution*, *370*, 125871. https://doi.org/10.1016/j.envpol.2025.125871

Mahmood, A., Farooq, A., Akbar, H., Ghani, H. U., and Gheewala, S. H. (2023). An Integrated Approach to Analyze the Progress of Developing Economies in Asia toward the Sustainable Development Goals. *Sustainability*, *15*(18), 13645. https://doi.org/10.3390/su151813645

Masood, T., Israr, A., Zubair, M., and Qazi, U. W. (2023). Assessing challenges to sustainability and resilience of energy supply chain in Pakistan: A developing economy from Triple Bottom Line and UN SDGs' perspective. *International Journal of Sustainable Energy*, *42*(1), 268–288. https://doi.org/10.1080/14786451.2023.2189489

Meyer, I. (2022). *Landnutzung im Klimawandel: Herausforderungen für eine zukunftsfähige Landwirtschaft*. Umweltökologisches Symposium. Höhere Bundeslehr- und Forschungsanstalt für Landwirtschaft Raumberg-Gumpenstein.

Miao, Q., and Nduneseokwu, C. (2024). Global Environmental Leadership: Addressing the Triple Planetary Crisis. In Q. Miao and C. Nduneseokwu, *Environmental Leadership in a VUCA Era* (pp. 37–119). Springer Nature Singapore. https://doi.org/10.1007/978-981-96-0324-4_2

Noyes, P. D., Miranda, D., Oliveira De Carvalho, G., Perfetti-Bolaño, A., Guida, Y., Barbosa Machado Torres, F., Paulo Machado Torres, J., Miglioranza, K. S. B., Hatje, V., and Barra, R. O. (2025). Climate change drives persistent organic pollutant dynamics in marine environments. *Communications Earth & Environment*, *6*(1), 363. https://doi.org/10.1038/s43247-025-02348-4

Onyenekwe, C., Okpara, U., Opata, P., Egyir, I., and Sarpong, D. (2022). The Triple Challenge: Food Security and Vulnerabilities of Fishing and Farming Households in Situations Characterized by Increasing Conflict, Climate Shock, and Environmental Degradation. *Land*, *11*(11), 1982. https://doi.org/10.3390/land11111982

Panza, L., Bruno, G., and Lombardi, F. (2023). Integrating Absolute Sustainability and Social Sustainability in the Digital Product Passport to Promote Industry 5.0. *Sustainability*, *15*(16), 12552. https://doi.org/10.3390/su151612552

Paulillo, A., and Sanyé-Mengual, E. (2024). Approaches to incorporate Planetary Boundaries in Life Cycle Assessment: A critical review. *Resources, Environment and Sustainability*, *17*, 100169. https://doi.org/10.1016/j.resenv.2024.100169

Pereira, P., Inacio, M., Barcelo, D., and Zhao, W. (2025). Impacts of agriculture intensification on biodiversity loss, climate change and ecosystem services. *Current Opinion in Environmental Science & Health*, *46*, 100637. https://doi.org/10.1016/j.coesh.2025.100637

Pörtner, H.-O., Scholes, R. J., Agard, J., Archer, E., Arneth, A., Bai, X., Barnes, D., Burrows, M., Chan, L., Cheung, W. L. (William), Diamond, S., Donatti, C., Duarte, C., Eisenhauer, N., Foden, W., Gasalla, M. A., Handa, C., Hickler, T., Hoegh-Guldberg, O., … Ngo, H. (2021). *Scientific outcome of the IPBES-IPCC co-sponsored workshop on biodiversity and climate change*. Zenodo. https://doi.org/10.5281/zenodo.5101125

Quagliarotti, D. A. L. (2023). The Water-Energy-Food Nexus in the Mediterranean Region in a scenario of polycrisis. *TeMA - Journal of Land Use, Mobility and Environment*, 109-122 Pages. https://doi.org/10.6093/1970-9870/10308

Reise, J., Siemons, A., Böttcher, H., Urrutia, C., Schneider, R., Iwaszuk, E., McDonald, H., Frelih-Larsen, A., Duin, L., and Mckenna, D. (2022). *Nature-based solutions and global climate protection. Assessment of their global mitigation potential and recommendations for international climate policy*. German Environment Agency.

Reusswig, F. (2022). *Ganz normale Katastrophen. Biodiversitätsverlust, Klimawandel und Covid-19-Pandemie als Anthropozän-Krisen*. Bundesamt für Naturschutz. https://bfn.bsz-bw.de/frontdoor/deliver/index/docId/1089/file/Schrift641.pdf

Richardson, K., and al., et. (2023). Earth beyond six of nine planetary boundaries. *Science Advances*, *9*, eadh2458. https://doi.org/10.1126/sciadv.adh2458

Rockström, J., Gupta, J., Qin, D., Lade, S. J., Abrams, J. F., Andersen, L. S., Armstrong McKay, D. I., Bai, X., Bala, G., Bunn, S. E., Ciobanu, D., DeClerck, F., Ebi, K., Gifford, L., Gordon, C., Hasan, S., Kanie, N., Lenton, T. M., Loriani, S., … Zhang, X. (2023). Safe and just Earth system boundaries. *Nature*, *619*(7968), 102–111. https://doi.org/10.1038/s41586-023-06083-8

Ryberg, M. W., Owsianiak, M., Richardson, K., and Hauschild, M. Z. (2016). Challenges in implementing a Planetary Boundaries based Life-Cycle Impact Assessment methodology. *Journal of Cleaner Production*, *139*, 450–459. https://doi.org/10.1016/j.jclepro.2016.08.074

Ryberg, M. W., Owsianiak, M., Richardson, K., and Hauschild, M. Z. (2018). Development of a life-cycle impact assessment methodology linked to the Planetary Boundaries framework. *Ecological Indicators*, *88*, 250–262. https://doi.org/10.1016/j.ecolind.2017.12.065

Sakschewski, B., Caesar, L., Andersen, L., Bechthold, M., Bergfeld, L., Beusen, A., Billing, M., Bodirsky, B. L., Botsyun, S., Dennis, D. P., Donges, J., Dou, X., Eriksson, A., Fetzer, I., Gerten, D., Häyhä, T., Hebden, S., Heckmann, T., Heilemann, A., … Rockström, J. (2025). Planetary Health Check 2025: A Scientific Assessment of the State of the Planet. In *Planetary Boundaries Science (PBScience)* (p. 144 pages, 22 MB) [Application/pdf]. Potsdam Institute for Climate Impact Research (PIK). https://doi.org/10.48485/PIK.2025.017

Schäffer, A., Groh, K. J., Sigmund, G., Azoulay, D., Backhaus, T., Bertram, M. G., Carney Almroth, B., Cousins, I. T., Ford, A. T., Grimalt, J. O., Guida, Y., Hansson, M. C., Jeong, Y., Lohmann, R., Michaels, D., Mueller, L., Muncke, J., Öberg, G., Orellana, M. A., … Scheringer, M. (2023). Conflicts of Interest in the Assessment of Chemicals, Waste, and Pollution. *Environmental Science & Technology*, *57*(48), 19066–19077. https://doi.org/10.1021/acs.est.3c04213

Scheffran, J. (2023). Klimawandel als Risikoverstärker: Kipppunkte, Kettenreaktionen und komplexe Krisen. In G. P. Brasseur, D. Jacob, and S. Schuck-Zöller (Eds.), *Klimawandel in Deutschland* (pp. 361–371). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-662-66696-8_27

Schmid, J. C., and Schwienhorst-Stich, E.-M. (2023). Planetare Gesundheit – Ein holistisches Gesundheitskonzept inmitten multipler planetarer Krisen. *Zeitschrift Für Medizinische Ethik*, *69*(4), 513–547. https://doi.org/10.30965/29498570-20230050

Schmidt, C., Kühnel, D., Materić, D., Stubenrauch, J., Schubert, K., Luo, A., Wendt-Potthoff, K., and Jahnke, A. (2024). A multidisciplinary perspective on the role of plastic pollution in the triple planetary crisis. *Environment International*, *193*, 109059. https://doi.org/10.1016/j.envint.2024.109059

Scientist's Coalition for an Effective Plastics Treaty. (2024). *Policy Brief: Cutting Plastic Pollution at the Source: The Case for Upstream Solutions*. Scientist's Coalition for an Effective Plastics Treaty. https://ikhapp.org/wp-content/uploads/2024/11/Cutting-Plastic-Pollution-at-the-Source-The-Case-for-Upstream-Solutions-2.pdf

Seck, S. (2022). Business, Human Rights, & the Triple Planetary Crisis: Confronting Overconsumption. *Articles, Book Chapters, & Popular Press*. https://digitalcommons.schulichlaw.dal.ca/scholarly_works/752

Sembiring, M. (2021). *Planetary Health and Triple Planetary Crisis: Relevance for Multilateral Cooperation on Biodiversity Protection and Conservation in Southeast Asia*. S. Rajaratnam School of International Studies. https://www.jstor.org/stable/resrep36219

Sharma, P., Reitz, T., Singh, S. P., Worrich, A., and Muehe, E. M. (2025). Going beyond improving soil health: Cover plants as contaminant removers in agriculture. *Trends in Plant Science*, S1360138525000305. https://doi.org/10.1016/j.tplants.2025.01.009

Shen, M., Huang, W., Chen, M., Song, B., Zeng, G., and Zhang, Y. (2020). (Micro)plastic crisis: Un-ignorable contribution to global greenhouse gas emissions and climate change. *Journal of Cleaner Production*, *254*, 120138. https://doi.org/10.1016/j.jclepro.2020.120138

Sigmund, G., Ågerstrand, M., Antonelli, A., Backhaus, T., Brodin, T., Diamond, M. L., Erdelen, W. R., Evers, D. C., Hofmann, T., Hueffer, T., Lai, A., Torres, J. P. M., Mueller, L., Perrigo, A. L., Rillig, M. C., Schaeffer, A., Scheringer, M., Schirmer, K., Tlili, A., … Groh, K. J. (2023). Addressing chemical pollution in biodiversity research. *Global Change Biology*, *29*(12), 3240–3255. https://doi.org/10.1111/gcb.16689

Sjöstedt, B., and Hulme, K. (2023). Re-evaluating international humanitarian law in a triple planetary crisis: New challenges, new tools. *International Review of the Red Cross*, *105*(924), 1238–1266. https://doi.org/10.1017/S1816383123000449

Soust-Verdaguer, B., Bernardino Galeana, I., Llatas, C., Montes, M. V., Hoxha, E., and Passer, A. (2022). How to conduct consistent environmental, economic, and social assessment during the building design process. A BIM-based Life Cycle Sustainability Assessment method. *Journal of Building Engineering*, *45*, 103516. https://doi.org/10.1016/j.jobe.2021.103516

Sugathapala, T. M., Capuano, T., Brandt, L., Iudicone, D., and Sardina, G. (2025). Vertical transport of buoyant microplastic particles in the ocean: The role of turbulence and biofouling. *Environmental Pollution*, *369*, 125819. https://doi.org/10.1016/j.envpol.2025.125819

Syberg, K., Gündoğdu, S., Olsen, T., Knoblauch, D., Oturai, N., Walker, T. R., Palm, E., Christensen, T. B., and Tangri, N. (2025). A circular plastic economy should account for all societal costs. *Cambridge Prisms: Plastics*, 1–10. https://doi.org/10.1017/plc.2025.10019

Tan, A. S. T., Uthayakumar, H., Yeo, L. S., Kong, K. G. H., Lo, S. L. Y., Andiappan, V., Loy, A. C. M., Teng, S. Y., and How, B. S. (2024). Shapley-Shubik Agents Within Superstructure-Based Recycling Model: Circular Economy Approaches for Fish Waste Eco-Industrial Park. *Process Integration and Optimization for Sustainability*, *8*(2), 487–501. https://doi.org/10.1007/s41660-024-00391-w

Theurl, M. C., Lauk, C., Kalt, G., Mayer, A., Kaltenegger, K., Morais, T. G., Teixeira, R. F. M., Domingos, T., Winiwarter, W., Erb, K.-H., and Haberl, H. (2020). Food systems in a zero-deforestation world: Dietary change is more important than intensification for climate targets in 2050. *Science of The Total Environment*, *735*, 139353. https://doi.org/10.1016/j.scitotenv.2020.139353

Trasande, L., Krithivasan, R., Park, K., Obsekov, V., and Belliveau, M. (2024). Chemicals Used in Plastic Materials: An Estimate of the Attributable Disease Burden and Costs in the United States. *Journal of the Endocrine Society*, *8*(2), bvad163. https://doi.org/10.1210/jendso/bvad163

Trust, S., Saye, L., Bettis, O., Bedenham, G., Hampshire, O., Lenton, T. M., and Abrams, J. F. (2025). *Planetary Solvency–finding our balance with nature Global risk management for human prosperity*. University of Exeter, Institute and Faculty of Actuaries. https://actuaries.org.uk/media/wqeftma1/planetary-solvency-finding-our-balance-with-nature.pdf

UNEN. (2021). *New Economics for Sustainable Development—Circular Economy*. United Nations Economist Network. https://www.un.org/sites/un2.un.org/files/circular_economy_14_march.pdf

UNEP. (2006). *Who are local communities?* United Nations Environment Programme. https://www.cbd.int/doc/meetings/tk/wscblac-01/information/wscblac-01-inf-05-en.doc

UNEP. (2023, November 12). *World must place human rights at heart of environmental protection: UNEP Executive Director*. United Nations Environment Programme. https://www.unep.org/news-and-stories/video/world-must-place-human-rights-heart-environmental-protection-unep-executive

UNEP (Ed.). (2024). *Global Resources Outlook 2024: Bend the trend—Pathways to a liveable planet as resource use spikes*. International Resource Panel.

Usman, S., Parker, M., and Vallat, M. (2025). *Dry-roasted NUTS: Early estimates of the regional impact of 2025 extreme weather * SSRN. https://doi.org/10.2139/ssrn.5484206

Villarrubia-Gómez, P., Carney Almroth, B., Eriksen, M., Ryberg, M., and Cornell., S. E. (2024). Plastics pollution exacerbates the impacts of all planetary boundaries. *One Earth*, *7*(12), 2119–2138. https://doi.org/10.1016/j.oneear.2024.10.017

WEF. (2025). *The Global Risks Report 2025*. World Economic Forum. https://reports.weforum.org/docs/WEF_Global_Risks_Report_2025.pdf

Wescombe, N. J., Martínez, J. G., Jehn, F. U., Wunderling, N., Tzachor, A., Sandström, V., Cassidy, M., Ainsworth, R., and Denkenberger, D. (2025). It’s time to consider global catastrophic food failures. *Global Food Security*, *46*, 100880. https://doi.org/10.1016/j.gfs.2025.100880

WHO. (2021). *Fast Facts on Climate Change and Health*. World Health Organization. https://www.who.int/publications/m/item/fast-facts-on-climate-change-and-health

Williams, A., Perego, P., and Whiteman, G. (2024). Boundary Conditions for Organizations in the Anthropocene: A Review of the Planetary Boundaries Framework 10 Years On. *Journal of Management Studies*, joms.13150. https://doi.org/10.1111/joms.13150

Wittmer, H., Berghöfer, A., Büttner, L., and Chakrabarty, R. (2021). *Es geht um unsere Lebensgrundlage: Wie wir jetzt handeln können, um die globalen Gemeingüter Biodiversität, Wälder und Meere für eine lebenswerte Zukunft zu erhalten*. Helmholtz-Zentrum für Umweltforschung (UFZ).

WWF. (2024). *WWF Living Planet Report 2024 A system in peril*. World Wildlife Fund (WWF). https://wwflpr.awsassets.panda.org/downloads/2024-living-planet-report-a-system-in-peril.pdf

Yates, J., Deeney, M., Muncke, J., Carney Almroth, B., Dignac, M.-F., Castillo, A. C., Courtene-Jones, W., Kadiyala, S., Kumar, E., Stoett, P., Wang, M., and Farrelly, T. (2025). Plastics matter in the food system. *Communications Earth & Environment*, *6*(1), 176. https://doi.org/10.1038/s43247-025-02105-7

Zhou, Z., Duan, X., Yu, Y., Ma, L., Moreno, A., Xia, Y., Chen, L., Ye, S., and Cong, R. (2025). Recent Advances and Applications of NMR Techniques in Plastic Characterizations. *Analytical Chemistry*, acs.analchem.4c05230. https://doi.org/10.1021/acs.analchem.4c05230

A Appendix

A.1 Methodology used for the literature search and analysis

A systematic literature search was carried out to compile relevant publications for subsequent analysis. The search was primarily conducted via *Web of Science* and *Google Scholar*, focusing deliberately on the period from 2020 to 2025 to ensure the inclusion of recent research findings and emerging insights.

Core keywords were defined in both German and English. Examples include: "Triple Crisis", "Dreifachkrise", "Polycrisis", "Polykrise", "Multiple crisis", "Mehrfachkrise", "Climate change", "Klimawandel", "Biodiversity loss", "Biodiversitätsverlust", and "Environmental pollution", "Umweltverschmutzung". Additional terms such as "Resilience", "Resilienz", "Governance", and "Transformative change" were included to capture cross-cutting issues and conceptual linkages. These keywords were first tested individually and then in various two- and three-term combinations. We then assessed the relevance of the articles based on titles, keywords, and, where available, abstracts. All identified and relevant sources were documented in a structured Excel database. The collected results were then screened in greater detail to compile a high-quality and thematically appropriate literature list for this analysis. Particular emphasis was placed on studies that:

- Directly address the triple/multiple crisis or its components (climate change, biodiversity loss, environmental pollution)
- Offer interdisciplinary or systemic perspectives, e.g. on governance, resilience, or transformative processes
- Explore interlinkages, synergies, or key drivers and
- were published between 2020 and 2025.

Throughout the process, literature recommendations from experts were continuously integrated and, if relevant, added to the Excel database. 71 sources form part of the database and serve as the foundation for the analysis in this report, while we used more literature for the report than were included in the SVTEEG analysis.

The literature analysis was supported by use of the artificial intelligence language model ChatGPT (GPT-4o). Each article was uploaded to the model and processed using a pre-defined set of prompts, instructing the AI to screen the documents according to the SVTEEG framework, generate abstracts, and suggest relevant analytical quotes. Results were catalogued in a structured Excel matrix using only predefined categories and keywords. The AI was instructed to focus on the explicit content provided within the uploaded documents, without reference to external knowledge. Human experts thoroughly checked every answer provided by the AI against the original source from which the material was obtained to ensure that incorrect or hallucinated information did not make it into the data. A record of this verification step was kept as metadata, including what was verified and by whom. The use of AI increased the amount literature that could be reviewed, mapped and structured for use by the experts working in the project. However, selection bias cannot be ruled out regarding the specific elements AI surfaced in its responses.

A.2 Analytical SVTEEG view

As part of the analysis, key contents of the literature review were also clustered according to the "SVTEEG" framework, which comprises *social/values, technological, economic, environmental and governance* factors (based on the STEEP method).[5] Table 1 provides an overview of this framework.

Table 1: SVTEEG categories used for the analysis

SVTEEG dimensions and their operationalisation

SVTEEG dimensions	Operationalised description of the SVTEEG dimensions
Socio-cultural and Values **S/V**	Encompasses the broad range of societal characteristics (global scope; state and trends) that may drive or hinder global sustainability. Includes values and preferences.
Technological **T**	Used for technologies and technological systems (global scope; status and trends). This includes research and development, diffusion, scaling and trends that may drive or hinder global sustainability.
Economic and Financial **E**	Includes the level and distribution of economic activity, structures, competitiveness, government spending/procurement, unemployment, markets and financial dynamics (global scale; status and trends) that can drive or hinder global sustainability.
Environmental and Ecological **E2**	Identifies climate change, biodiversity, pollution, food, soil, water, wind, energy, natural resources and environmental regulations (global scope; status and trends) that can drive or hinder global sustainability.
Governance and Politics **G**	Includes political positions, political forces/parties/interests, policy/governance, (in)stability, regulatory framework, tax policy, price controls, trade policy (global scope; status and trends) that can drive or hinder global sustainability.
Multiple SVTEEG dimensions **M**	Used for cases where sources mention several SVTEEG dimensions and their interactions that could drive or hinder global sustainability.

Source: own illustration, Ecologic Institute.

In a database used for the literature review feeding into this report, each source used was tagged according to the various SVTEEG dimensions it deals with. In the following a condensed version of the SVTEEG analysis is presented (Table 2). Although M (multiple SVTEEG dimensions) was foreseen for the analysis, this aspect was omitted since almost all of the sources covered at least two aspects, meaning we would have needed to tag almost all of the sources with M, which would have made its addition less useful.

[5] STEEP stands for the five key factors examined using that analytical method: socio-cultural, technological, economic, environmental/ecological, and political. These factors have been adapted for the SVTEEG analysis used in this report.

Table 23: SVTEEG analysis

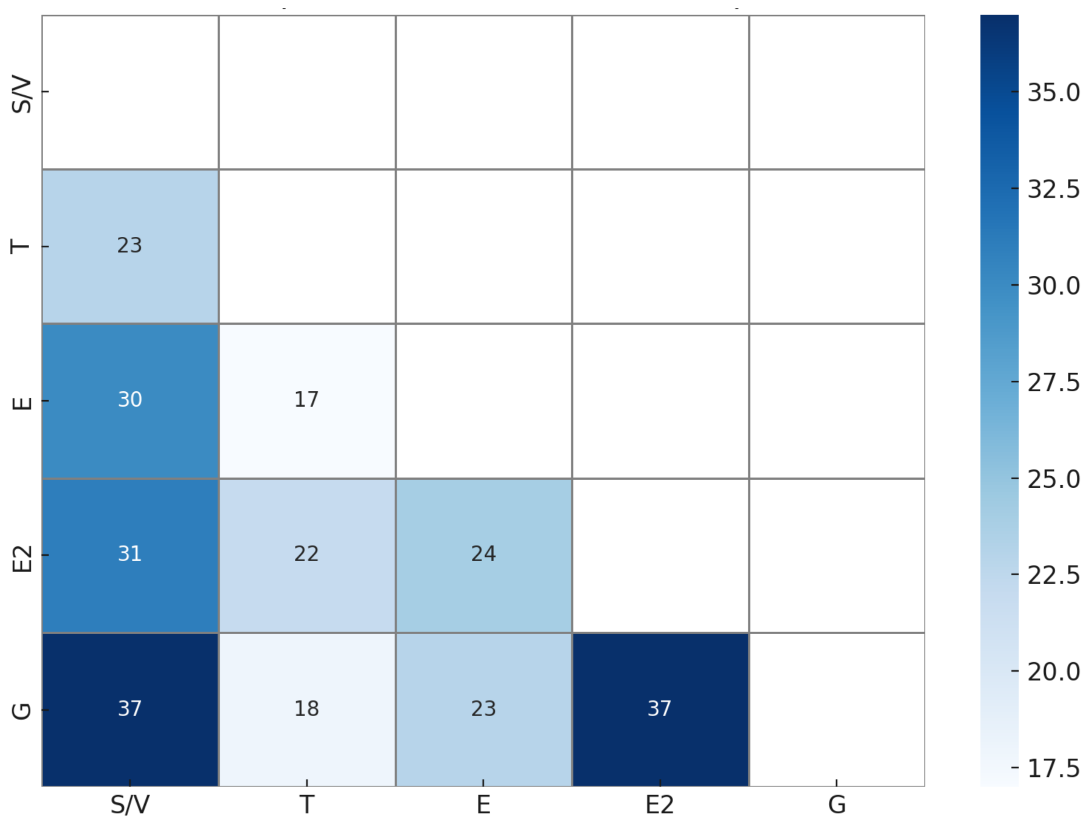
The continuum from one-dimensional to five-dimensional contributions, and how it can be used.

Source	S/V	T	E	E2	G
Bachmann et al. (2023)	S/V	T	E	E2	
Berti (2020)	S/V		E	E2	G
Brocchi (2024)	S/V		E	E2	G
Brosig (2025)	S/V	T			G
Bucksch & Schlicht (2023)	S/V		E	E2	G
Bunsen et al. (2021)	S/V			E2	G
Carney Almroth and Villarrubia-Gómez (2024)	S/V	T	E	E2	G
Carroll et al. (2023)	S/V	T		E2	G
Casonato et al. (2024)	S/V	T		E2	G
Chungyalpa et al. (2025)	S/V		E	E2	G
Corbane et al. (2024)				E2	G
Cozzolino et al. (2025)	S/V	T	E	E2	
Destoumieux-Garzón et al. (2022)				E2	G
Diller (2024)	S/V	T	E	E2	G
Drenckhahn et al. (2020)	S/V		E	E2	G
ECHOES et al. (2024)	S/V			E2	G
Essien et al. (2025)	S/V				
Fady et al. (2025)	S/V		E		
Ferraz & Barreira (2024)	S/V				G
Fisher et al. (2024)	S/V				
Frey et al. (2023)	S/V		E	E2	G
Ghani et al. (2023)	S/V		E		
Haderer et al. (2023)	S/V	T	E	E2	G
Halpe et al. (2025)		T	E	E2	
Hansen et al. (2024)	S/V			E2	
Hartley et al. (2024)	S/V	T			G
He & James (2021)	S/V	T		E2	G
Hege (2025)	S/V				G
Hellin et al. (2023)	S/V		E	E2	G
Hellweg et al. (2023)		T	E		
Hertig et al. (2023)	S/V	T	E	E2	G
Herzog & Kondratjuk (2024)	S/V	T	E	E2	G
Ihsan et al. (2024)	S/V	T	E		
IPBES (2024a)	S/V	T		E2	G
IPBES (2024b)	S/V				G
IPCC (2023b)	S/V		E	E2	G
Kozban et al. (2023)			E	E2	G
Kurth et al. (2020)	S/V	T	E	E2	G
Lan et al. (2025)				E2	
Mahmood et al. (2023)	S/V	T	E		
Masood et al. (2023)				E2	G
Meyer (2022)	S/V	T		E2	G
Miao & Nduneseokwu (2024)	S/V		E		
Onyenekwe et al. (2022)				E2	G
Panza et al. (2023)		T		E2	G

Source	S/V	T	E	E2	G
Paulillo & Sanyé-Mengual (2024)			E		G
Quagliarotti (2023)				E2	G
Reise et al. (2022)	S/V			E2	G
Reusswig (2022)	S/V			E2	G
Richardson et al. (2023)		T		E2	G
Ryberg et al. (2018)		T	E		
Ryberg et al. (2016)	S/V	T			
Schäffer et al. (2023)	S/V		E		G
Scheffran (2023)	S/V		E	E2	G
Schmid & Schwienhorst-Stich (2023)	S/V	T	E		G
Schmidt et al. (2024)	S/V		E		G
Seck (2022)	S/V				G
Sembiring (2021)	S/V				
Sharma et al. (2025)		T	E	E2	
Shen et al. (2020)	S/V		E		
Sigmund et al. (2023)				E2	G
Sjöstedt & Hulme (2023)	S/V	T			
Soust-Verdaguer et al. (2022)	S/V	T	E	E2	
Sugathapala et al. (2025)		T		E2	
Tan et al. (2024)			E	E2	
Theurl et al. (2020)	S/V	T	E	E2	G
Villarrubia-Gómez et al. (2024)	S/V		E	E2	G
Williams et al. (2024)	S/V	T		E2	G
Wittmer et al. (2021)	S/V		E		G
Yates et al. (2025)				E2	G
Zhou et al. (2025)		T		E2	

The table shows that only seven articles cover all five dimensions. This does not mean, however, that these reports do not take a holistic perspective; it merely indicates that they have a specific focus. Accordingly, this list can serve as an introduction to the literature, providing information on which dimension(s) each report or article addresses. (Abstracts and excerpts can also be searched in the Excel database.)
Source: own illustration, Ecologic Institute.

Figure 3: Co-occurrence heatmap of SVTEEG dimensions



The heatmap reveals which dimensions are most often mentioned together. Darker cells with higher numbers indicate stronger co-occurrence between two dimensions.
Source: own illustration, Ecologic Institute.

We used a set of specific search terms over a defined time period to identify literature, and this must be kept in mind when working with and examining the SVTEEG categories. The heatmap shows that E2 (environmental and ecological aspects) most frequently co-occurs with G (governance), occurring together 37 times. At the same time, socio-cultural and values (S/V) aspects occur equally often alongside governance (G) (37 times), closely followed by S/V with environmental and ecological aspects (E2), i.e. 31 times. In contrast, T (technology) and E (economics and finance) co-occur less frequently with the other aspects and form the weakest pair. Furthermore, only seven articles mention all five aspects. This is interesting given that we explicitly aimed to capture cross-cutting issues and conceptual linkages with our search terms and combinations.

In this selection of literature, E2 (environmental and ecological aspects) and G (governance) are the most interconnected dimensions, together with S/V (socio-cultural and values) and G (governance). This indicates that discussions about governance are most often linked to environmental and ecological issues. G (governance), E2 (environmental and ecological aspects) and S/V (socio-cultural and values) form a core cluster — the strong interlinkages between these aspects suggest that they form the backbone of the literature's framing. T (technology) and E (economics and finance) are the least integrated, despite being expected to be central to a systemic polycrisis. Regarding its use, it should be noted that SVTEEG is a framework that: 1) groups factors together for a better human understanding, and 2) identifies factor pairs/groups where important interdependencies are documented/analysed.