CLIMATE CHANGE
83/2025

Interim report

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

by:
Natalia Burgos Cuevas, Yannick Heni, Teresa Spantzel,
Charlotte Felthöfer, Hannah Brunkhorst, Doris Knoblauch,
Arne Riedel
Ecologic Institute, Berlin

publisher:
German Environment Agency

CLIMATE CHANGE 83/2025

AA-Forschungsplan of the Federal Foreign Office

Project No. (FKZ) 3724 41 703 0
FB001913/ENG

Interim report

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.

by
Natalia Burgos Cuevas, Yannick Heni, Teresa Spantzel,
Charlotte Felthöfer, Hannah Brunkhorst, Doris Knoblauch,
Arne Riedel
Ecologic Institute, Berlin

On behalf of the German Environment Agency

Imprint

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

Report performed by:
Ecologic Institute
Pfalzburger Str. 43/44
10717 Berlin
Germany

Report completed in:
September 2025

Edited by:
Section V 1.1 International Climate Action
Tobias Herzfeld (Fachbegleitung)

DOI:
https://doi.org/10.60810/openumwelt-8108

ISSN 1862-4359

Dessau-Roßlau, December 2025

Abstract: Moving from interconnected crises to systemic solutions

The triple planetary crisis of climate change, biodiversity loss, and pollution constitutes an interconnected system of risks, driven by unsustainable resource extraction and processing, fossil fuel dependence, and entrenched social and economic inequalities. Its impacts are distributed unequally, with Indigenous Peoples, women, youth, and countries of the Global South among the Most Affected People and Areas (MAPA), bearing the heaviest burdens while having the least influence over decisions.

Current policy responses remain fragmented, focusing on single issues rather than addressing systemic and underlying drivers. This report provides an integrated perspective by examining three mutually reinforcing pathways: governing societal metabolism and resource use through efficiency, sufficiency, and equity; scaling up nature-based solutions (NbS) to restore ecosystems, reduce emissions, and curb pollution while enhancing well-being; and advancing systemic transformation that reorganizes governance, markets, and societal values to embed justice and resilience at their core. The analysis concludes that the triple crisis can only be effectively addressed through systemic, cross-sectoral, and justice-oriented approaches. By linking resource governance, NbS, and transformative change, this report highlights how today's triple crisis can be turned into an opportunity to regenerate ecosystems, reduce inequalities, and build resilient societies within planetary boundaries.

Kurzbeschreibung: Von multiplen Krisen zu systemischen Lösungsansätzen – Ressourceneffizienz, naturbasierte Lösungen und Transformation als Wege aus der dreifachen planetaren Krise

Die planetare Dreifachkrise aus Klimawandel, Biodiversitätsverlust und Umweltverschmutzung bildet ein vernetztes System von Risiken, das durch nicht-nachhaltige Ressourcengewinnung und -verarbeitung, die Abhängigkeit von fossilen Energieträgern sowie tief verwurzelte soziale und wirtschaftliche Ungleichheiten angetrieben wird. Die Folgen sind ungleich verteilt: Besonders betroffen sind indigene Völker, Frauen, Jugendliche sowie Länder des Globalen Südens, die zu den „Most Affected People and Areas“ (MAPA) zählen. Sie tragen die größten Lasten, haben jedoch meist den geringsten Einfluss auf Entscheidungen.

Politische Antworten bleiben bislang fragmentiert und greifen häufig einzelne Probleme auf, ohne die systemischen und zugrunde liegenden Ursachen anzugehen. Der Bericht bietet daher eine integrierte Perspektive entlang von drei sich gegenseitig verstärkenden Handlungsfeldern: Erstens der Steuerung von Ressourcenflüssen und gesellschaftlichem Stoffwechsel durch Effizienz, Suffizienz und Gerechtigkeit; zweitens der Skalierung naturbasierter Lösungen (NbS), die Ökosysteme wiederherstellen, Emissionen senken und Verschmutzung verringern, während sie zugleich das menschliche Wohlergehen fördern; sowie drittens eine tiefgreifende systemische Transformation, die Governance, Märkte und gesellschaftliche Werte neu organisiert, um Gerechtigkeit und Resilienz in ihrem Kern zu verankern. Die Analyse kommt zu dem Schluss, dass die Dreifachkrise nur durch systemische, sektorübergreifende und gerechtigkeitsorientierte Ansätze wirksam bewältigt werden kann. Durch die Verbindung von Ressourcensteuerung, NbS und transformativen Veränderungen zeigt der Bericht, wie sich die heutige Dreifachkrise in eine Chance für die Regeneration von Ökosystemen, den Abbau von Ungleichheiten und den Aufbau widerstandsfähiger Gesellschaften innerhalb der planetaren Grenzen verwandeln lässt.

Table of Contents

List of tables

List of abbreviations

Abbreviation	Explanation
CBD	Convention on Biological Diversity
CE	Circular economy
CFS	Committee on World Food Security
CFFA	Coalition for Fair Fisheries Arrangements
CJRF	Climate Justice Resilience Fund
EU	European Union
FAO	Food and Agriculture Organization
GACERE	Global Alliance on Circular Economy and Resource Efficiency
GDP	Gross Domestic Product
GHG	Greenhouse gas
GIZ	German Society for International Cooperation
GLF	Galapagos Life Fund
IPBES	Intergovernmental Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IRP	International Resource Panel
IUCN	International Union for Conservation of Nature
LEAF Coalition	Lowering Emissions by Accelerating Forest finance Coalition
MAPA	Most affected people and areas
NbS	Nature-based Solutions
NBSAP	National Biodiversity Strategy and Action Plan
NDC	Nationally Determined Contributions (in Paris-Agreement)
NGO	Non-governmental organization
PIFWA	Penang Inshore Fishermen Welfare Association
SDG	Sustainable Development Goals
SUDS	Sustainable Urban Drainage Systems
UN	United Nations
UNEA	United Nations Environment Assembly
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Environment Programme
UNEP-ISC	United Nations Environment Programme - International Standard Industrial Classification of All Economic Activities

Abbreviation	Explanation
UNEP-WCMC	United Nations Environment Programme - World Conservation Monitoring Centre
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNGA	United Nations General Assembly
WWF	World Wildlife Fund

Glossary

Term	Explanation
Agenda 2030	The 2030 Agenda for Sustainable Development is a global action plan adopted by all United Nations member states in 2015. It consists of 17 Sustainable Development Goals (SDGs) aimed at ending poverty, protecting the planet, and ensuring peace and prosperity for all by 2030.
Agroecology	A sustainable farming approach that works with natural ecosystems to maintain agricultural productivity while supporting economic, social and environmental well-being. Agroecology aims to reduce negative impacts of agriculture, while also enhancing biodiversity and resilience for plants, animals and humans.
Agroforestry	An age-old yet new scientific practice of intercropping woody and non-woody plants like trees and shrubs. It combines principles from agriculture, horticulture, forestry, ecology, and soil science with the aim of benefitting nature, the economy, and communities altogether.
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.
Co-creation	Refers to collaborative methods of working that focus on open exchange and active participation allowing different stakeholders to share and expand their knowledge and skills together.
Co-production	Refers to a collaborative process in which different stakeholders collectively produce a specific outcome, e.g. knowledge, services or solutions. It highlights shared responsibility for an outcome that is meant to benefit all parties involved.
Ecological literacy	Often used interchangeably with ecoliteracy, referring to the understanding of functions of natural systems and how all organisms and ecosystems are inter-connected. It involves applying this knowledge to develop sustainable communities and responsibly manage interactions between society and the Earth's biosphere.
Entropy	A measure of disorder or randomness in a system. In physics, it describes how energy becomes less available for useful work as it spreads out. The same principle applies to materials, which tend to disperse and become less available for reuse over time.
Epistemology	A branch of philosophy that studies the nature, origin, and limits to human knowledge. Derived from the Greek episteme (”knowledge”) and logos (“reason”), it explores human beliefs, plus the reliability and scope of human knowledge.
Greywater	Wastewater generated from household activities such as bathing, handwashing, laundry, and dishwashing, excluding sewage from toilets.
Linear production	An economic model of production and consumption based on a one-way flow of resources: raw materials are extracted, transformed into products, used, and then discarded as waste.
Local communities	Non-indigenous groups of people that have longstanding connections to a specific place and its natural environment, often maintained over multiple generations. They are shaped by their history, culture, and livelihoods tied to a specific land.

Term	Explanation
More-than-human world	The concept was introduced by David Abram in 1996 and is used to challenge human-centered perspectives by emphasizing that qualities which are typically associated with humans, e.g. intelligence, emotion, purpose and agency, also exist in the natural world.
Nature-based Solutions	The UNEA (2022) defines Nature-based Solutions as “actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, resilience and biodiversity benefits”.
Paris Agreement	An international climate agreement that was adopted in 2015 under the United Nations Framework Convention on Climate Change (UNFCCC) to limit global warming well below 2°C, preferably 1.5°C, above pre-industrial levels. Amongst others it legally binds countries to reduce greenhouse gas emissions, strengthen climate resilience, and provide financial and technical support to developing nations.
Planetary boundaries	Thresholds in the Earth’s natural systems that define a space for humanity to live without causing large-scale environmental instability. They entail nine critical areas: climate change, biosphere integrity, land-system change, freshwater use, biogeochemical flows, ocean acidification, atmospheric aerosol loading, stratos-pheric ozone depletion, and novel entities such as synthetic chemicals, nuclear waste, and microplastics.
Product-as-a-service	A business model in which customers pay for the use or performance of a product rather than owning it outright. It is a common concept within circular economy and aimed at promoting resource efficiency.
Rebound effect	Unintended increases in resource use or emissions that occur when efficiency improvements lower the cost or environmental impacts of a good or service, leading to higher use in production and consumption.
Regenerative farming	A holistic approach to agriculture that focuses on improving soil health, biodiversity, and water cycles while reducing synthetic inputs to make farming more sustainable and climate-friendly.
Rio Convention	Refers to the international agreements that work together to promote sustainable development. Ther agreements are also known as three sister conventions, including the UNFCCC (Un Climate Change), the CBD (UN Biodiversity), and the UNCCD (UN Convention to Combat Desertification).
Sufficiency	The idea of consuming less rather than just consuming more efficiently. It is a complementing strategy within the circular economy. Sufficient lifestyles encourage reduction in material use and resource demand, with the aim of lowering the environmental impact in the face of climate change.
Sustainable Urban Drainage Systems	Sustainable Urban Drainage Systems (SuDS) are water management practices that mimic natural drainage processes in urban areas by promoting infiltration, evaporation, or storage of surface runoff, thereby reducing reliance on conventional drainage systems.
Syntropic agriculture	A nature-inspired agricultural system developed by Ernst Götsch that focuses on growing a variety of plants to gain a diverse vegetation over time, aiming at restoring ecosystems and having more resource abundance.
Transformative Pathways	Long-term strategies that guide how societies can achieve greenhouse gas emissions or limit global temperature rise. They involve coordinated changes in technology, behaviors, resource management, infrastructure, and institutions to shift how societies live, produce and consume towards more sustainable futures.

1 Introduction

This analysis builds on the report "The Interconnected Challenges of Climate Change, Biodiversity Loss and Environmental Pollution – Drivers, Interdependencies and Impacts of the Triple Planetary Crisis" (Knoblauch et al., 2025). The findings show that the triple planetary crisis–climate change, biodiversity loss, and pollution – has evolved into an integrated system of risks and feedback that now shapes the boundaries of planetary and human health. These crises are driven by human activities, particularly the accelerated extraction and processing of fossil fuels, minerals, and biomass, alongside deep-seated social and economic inequalities. Together, they constitute not three separate challenges, but a single, interconnected crisis.

The consequences of crossing seven out of nine planetary boundaries are profound and far-reaching. Climate change, soil degradation, chemical and plastic contamination, and biodiversity loss are eroding 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 to the cycling of nutrients, the regulation of water, and the sequestration of carbon in soils increasingly undermines the foundation of water and food security and livelihoods. At the same time, the triple planetary crisis poses direct health risks to human populations. These risks range from chronic diseases associated with chemical exposure and the emergence of new infectious diseases caused by ecological disruption and increased contact between humans and wildlife, to significant mental health strains.

The impacts are deeply unequal. Indigenous Peoples, low-income communities, women, youth, residents of informal settlements, and countries of the Global South. These Most Affected People and Areas (MAPA) face heightened exposure to climate hazards, biodiversity loss, and pollution, yet have the least influence over governance and resource allocation. These groups are often overlooked or undervalued in research, policymaking and implementation, creating a risk that solutions will perpetuate the very inequalities they aim to address.

To meet the multifaceted challenges of the crises, the same interconnected forces driving the crisis must be met with equally interconnected responses – solutions that cut across sectors, tackle root causes, and deliver co-benefits for people and planet. Recognizing this complexity underscores why incremental or single-issue approaches are no longer enough. Tackling climate change in isolation or addressing pollution without confronting resource overuse or biodiversity loss risks shifting pressures rather than resolving them. Equally, pursuing solutions without addressing underlying inequalities or the undervaluation of nature risks perpetuating the very conditions that created the crisis in the first place. What is needed are solutions that respond to the interconnected drivers of the crisis – solutions that are systemic, integrated, and transformative.

This report explores three such pathways. It examines how increasing resource and material efficiency can reduce environmental pressures at their source, how nature-based solutions can restore ecosystems and strengthen resilience, and how deep systemic change can confront structural inequalities, integrate diverse knowledge systems, and embed the value of nature into governance and decision-making. Taken together, these approaches move beyond fragmented, symptom-oriented measures, offering a coherent vision for change that addresses the root causes of the triple planetary crisis.

By linking ecological, social, and economic dimensions, these solutions open space for transformation. They demonstrate that the triple crisis is not only a challenge but also an opportunity to rethink how societies relate to nature, how they govern resources, and how they distribute risks and benefits. In this way, they lay the foundation for a more just, resilient, and regenerative future.

2 Societal metabolism and resource use: Strategies for staying within planetary boundaries

2.1 The central role of resource use in the triple planetary crisis

According to the UN Environment Programme (UNEP), material use has tripled in the last 50 years and reached more than 100 billion tonnes annually (UNEP, 2024): Following the current trajectory, it is expected to rise by more than 2.3% per year. Major contributors to this growth are four provisioning systems that are central for meeting human needs: the built environment and mobility systems, followed by food and energy systems. These four domains together drive 90% of material demand globally. Projections suggest that, without significant systemic changes, material extraction could increase by nearly 60% by 2060, far overshooting sustainable levels.

Material use can serve as a practical proxy for environmental impact by reflecting the general link between material flows and associated environmental effects. Also, to analyse the link between resource use, economic activity, and environmental change the concept of societal metabolism is used. It refers to the continuous flow of materials and energy through economies to sustain themselves (see Box 1) (Haberl et al., 2019). Most environmental problems are the result of this societal metabolism. The triple planetary crisis – climate change, biodiversity loss, and pollution – is largely the result of both input-side pressures (extraction, land use) and output-side consequences (waste, GHG emissions, pollutants).

Box 1: Societal metabolism

Societal metabolism refers to the biophysical processes through which human societies interact with the environment to sustain themselves. Analogous to the metabolism of living organisms, societies extract low-entropy materials and energy – such as biomass, minerals, and fossil fuels – from nature, transform them through economic activity, and eventually release them as high-entropy waste, including emissions and pollutants. This continuous flow maintains the material infrastructure and functioning of society (Georgescu-Roegen, 1971).

However, unlike natural ecosystems – where metabolic exchanges are embedded in ecological relations – societal metabolism is mediated by social structures: institutions, technologies, cultural norms, power relations, and economic systems (Haberl et al., 2019). These social mediations shape how resources are accessed, used, and distributed, and determine the scale and intensity of environmental pressures (Pineault, 2025).

Societal metabolism thus serves as a conceptual bridge between ecological and social analysis. It highlights how natural processes and social relations are co-constitutive, and how the organization of economic systems – for example, due to dependence on continuous growth under capitalism – can lead to unsustainable patterns of resource use and environmental degradation. Understanding societal metabolism is essential for addressing the structural roots of the triple crisis and designing just and sustainable modes of provisioning.

The environmental consequences of the fossil-based industrial metabolism are staggering: resource extraction and processing account for over 55% of global GHG emissions and more than 90% of biodiversity loss and water stress when land-use change is included (UNEP, 2024). The prevailing model of resource use not only accelerates ecological breakdown but also results in deeply unequal distributions of environmental benefits and harms (Millward-Hopkins et al., 2025).

In a context of ongoing change and interconnected crises effective resource use management is essential for strengthening human security and meeting basic needs. The resource agenda is not solely environmental; it underpins the long-term capacity of natural systems to sustain equitable well-being and peaceful development. To achieve global goals on climate, biodiversity, pollution, land restoration, and human development, it is critical to adopt a resource perspective (UNEP, 2024).

The circular economy has emerged as the most prominent framework to address these challenges, yet it remains a contested concept, subject to differing interpretations and critiques regarding its transformative potential. To date, it has not been able to fulfil its promise. Only 11.2% of materials exiting the economy are waste destined for recycling, while 6.9% of materials entering the economy are secondary materials (Circle Economy and Deloitte, 2025).

2.2 Circular Economy and resource efficiency: promise and pitfalls

The circular economy (CE) has emerged as a prominent solution framework in addressing unsustainable resource use. At its core, CE seeks to reduce primary resource inputs and minimize waste and emissions through principles such as reduce, reuse, and recycle. These principles have been expanded into the 9R framework[1] (Potting et al., 2017), prioritizing refusal and rethinking of consumption before considering downstream strategies like recycling or recovery.

CE has gained wide traction in academia, policy, and business. Yet its conceptual foundations remain contested. Scholars describe it as an "essentially contested concept"(Calisto Friant et al., 2024), meaning that actors interpret and promote CE to align with their own political and economic agendas. It has also been argued that the term functions as a so-called floating signifier – a concept that allows for the articulation of highly diverse meanings and interests. The CE thus becomes a vehicle for depoliticization. It facilitates consensus among actors while simultaneously suppressing fundamental contradictions. It enables an implementation that is agreeable but limited and allows for engagement with the issue while maintaining the prevailing mode of operation (Rödl et al., 2022).

Inconsistent definitions of CE also lead to difficulties in quantifying the mitigation potential due to significant variations in study methods, system boundaries, and intervention scales. Diverse approaches at micro, meso, and macro levels complicate attempts to aggregate findings, hindering clear assessment of its overall impact on reducing environmental impacts (Cantzler et al., 2020).

Weak CE implementations tend to focus on technical fixes or recycling, while leaving the scale and structure of economic activity unchallenged. Therefore, they are not being effective enough in tackling the causes of the triple crisis. Calisto Friant (2024) notes that “dominant CE visions thus often neglect key issues and cycles related to wealth, power, care, race, gender, class, planetary boundaries, ecosystem limits, and democracy.” In contrast, more ambitious visions call for a repoliticization of the CE and a systemic reorganization of production and consumption – one that foregrounds equity, power dynamics, planetary limits, and social provisioning (e.g. Calisto Friant et al., 2024; Clube and Tennant, 2023; Genovese and Pansera, 2021; Tölg and Fuentes, 2025).

[1] The 9R framework consist of the following strategies (in order of decreasing circularity): R0 – Refuse, R1- Rethink, R2 – Reduce, R3 – Reuse, R4 – Repair, R5 – Refurbish, R6 – Remanufacture, R7 – Repurpose, R8 – Recycle and R9 – Recover.

It is thus essential to unravel the fundamental drivers of resource use. To give an example, Chakori et al. (2021) identify three interconnected subsystems influencing food packaging consumption: globalization, urbanization and the emergence of modern supermarkets[2], as well as time constraints faced by households. Addressing food packaging reduction therefore necessitates structural reforms beyond recycling and using sustainable materials.

2.3 Examples of circular and sustainable resource practices addressing the triple crisis

2.3.1 Resources and the built environment

Resource efficiency can significantly reduce emissions by decreasing demand for energy- and emissions-intensive materials. For example, applying CE-strategies in buildings – such as reducing and redistributing floor area, material substitution (e.g. with wood), and extending product lifespans – could cut emissions by up to 40% by 2050 in the G7 countries. Such strategies could contribute up to 20% of the carbon budget for limiting global warming to 1.5°C (Hertwich et al., 2020). Several notable examples can illustrate the impact of CE strategies in construction.

Box 2: Innovations in resource-efficient building

The CREE GmbH, an Austrian start-up, uses a patented timber-hybrid prefabrication system that reduces embodied emissions by up to 50% through material efficiency and standardisation. Gropyus, an Austrian-German firm, develops modular, prefabricated housing supported by digital platforms. Its automated factory in Germany targets 3,500 apartments annually, exemplifying scalable, resource-efficient construction (Ellen MacArthur Foundation, 2024).

Also, the Super Circular Estate project in the Netherlands repurposed 75–100% of materials from a 1968 apartment block to build three new homes using innovative reuse techniques. It coordinated demolition and construction simultaneously, developed new circular products, and engaged residents to maintain social cohesion by allowing them to return to the rebuilt community (ReBuilt, 2024).

These kinds of resource efficiency measures displayed in Box 2 should be complemented by improved use of vacant and underutilised spaces, alongside the promotion of community-oriented living that lessens the demand for new housing. When integrated with well-balanced neighbourhood designs – where essential services are accessible within walking or cycling distance – this approach can curb the expansion of built infrastructure, address fundamental demand drivers, and generate multiple co-benefits (IRP, 2023).

2.3.2 Closing loops in agriculture

Biomass extraction is a major driver of biodiversity loss and the agricultural sector a significant contributor to carbon emissions. Transitioning to circular agricultural systems – including regenerative farming, organic waste management, nutrient cycling, and reduced food waste – could help stay within ecological boundaries while maintaining food security. Dietary shifts, especially away from high-impact animal products, also play a critical role (Circle Economy and Deloitte, 2023; FAO, 2025; Guerrero-Villegas et al., 2025).

[2] Modern supermarkets refer to large-scale retail outlets offering one-stop shopping, and are dominant in global food markets. They consolidate market power, displace traditional retailers, and influence food systems through strict product standards, long supply chains, and packaging-driven marketing.

Box 3: Examples of circular agriculture

In rural India, circular farming practices are simultaneously enhancing livelihoods, improving resource efficiency, and strengthening community resilience. Supported by different initiatives from NGOs or government programmes, villages are establishing localised "waste-to-resource" loops. Organic residues – from kitchen waste to crop stubble – are converted into compost, biochar, and biogas, improving soil health, reducing air pollution, and lowering input costs. Plastic waste is addressed through agri-recycling cooperatives, biodegradable alternatives, and collection schemes, while greywater is treated via low-cost filtration systems and reused for irrigation, reducing reliance on groundwater. Circular energy solutions, including biomass fuels, solar pumps, and community biogas plants, further cut fossil fuel use and create new income streams (Sharma, 2025).

In Benin, the Songhai Integrated Farming Initiatives exemplify a closed-loop agricultural system that combines crop cultivation, livestock rearing, aquaculture, and renewable energy production. By applying CE principles, Songhai transforms crop residues into animal feed, converts animal waste into organic fertilizer, and produces biogas from organic matter–reducing dependence on external inputs and minimising environmental impacts. Beyond environmental benefits, the initiative prioritises community empowerment through training, job creation, and capacity building, thereby strengthening local economies and food security (Olusola and Oyewole, 2025).

2.3.3 Preventing and reducing pollution

Pollution often results from poor material design and linear production. Up to 80% of the environmental impacts of a product are determined at the design stage (European Commission, 2012). Applying CE principles can therefore eliminate pollution at the source. These principles include designing out waste and pollution through resource-efficient, recyclable, and non-toxic product design; keeping materials in use to limit primary material extraction; and regenerating nature through nature-positive activities. Also, in textiles alone, upstream circular strategies could generate US $700 billion in economic value and sharply reduce chemical, water, and air pollution (GACERE, 2024).

These measures should be complemented by upstream interventions at the level of provisioning systems. For rubber tyres – identified as a "ubiquitous and complex pollutant" (Mayer et al., 2024) – this entails a systemic shift towards public transport. This shift would be achieved by transforming the design of the mobility system itself: reducing travel demand through strategies such as remote working and compact urban planning, and developing infrastructure that prioritises public and active transport while minimising reliance on private vehicles (IRP, 2023).

2.4 Challenges, enabling conditions and policy levers

Achieving sustainable resource use requires addressing numerous challenges. For example, Kreinin et al. (2024) identify seven **fundamental structural barriers** impeding the sustainability of provisioning systems for food, mobility, housing, and leisure. These barriers comprise the economic growth paradigm, policy incoherence, entrenched vested interests, the externalization of environmental costs, prevailing narratives of the good life, social inequality, and the inadequate incorporation of environmental issues within educational frameworks. Similarly, according to UNEP (2024) the transition to sustainable resource use is constrained by reinforcing economic, institutional, and behavioural barriers. Market failures, harmful subsidies, entrenched investments, and concentrated corporate power lock in unsustainable practices. Resource-intensive consumption patterns, limited sustainable infrastructure, and gaps in education and skills hinder behavioural change. Fragmented governance, weak institutional capacity, and insufficient inclusion of local and scientific actors impede coordinated action. A lack of operational targets, transparency, and accessible information further constrains progress, while efficiency gains are often offset by rebound effects.

Overcoming these challenges demands responses that go beyond technical fixes. While improving resource efficiency and circularity – through strategies such as extending product lifespans, promoting reuse, and enhancing recycling– is indispensable, such measures remain constrained if structural drivers are not addressed. Tackling the dominance of growth-oriented economic policies, reorienting cultural narratives of the good life, and overcoming vested interests are essential to create enabling conditions for systemic change (see also chapter 4). Therefore, governing societal metabolism to stay within planetary boundaries includes fostering sustainable consumption and production patterns, alongside targeted interventions in resource- and impact-intensive provisioning systems[3] accompanied by broader transformations in governance, finance, trade, and education. Also, ensuring that measures are context-specific is key: while absolute decoupling of resource use from environmental impact is essential in high-income contexts, lower-income contexts may allow for some growth in resource use, provided environmental impact decoupling remains central. System-level changes in governance, finance and trade are necessary to create an enabling environment for a just and sustainable transition (UNEP, 2024).

Moreover, Steinberger et al. (2024) argue, that the democratization of provisioning systems is a crucial aspect of this transformation, as it integrates economic matters into the political sphere, broadens the decision-making authority of those impacted, fosters increased opportunities for deliberation, and moves away from private ownership and exploitation toward greater autonomy and freedom. This emphasizes "active participation and decision-making in the provision of what we all need to live well" and would therefore "place citizen decision-making about production, consumption, resource allocation, investment, and ownership at the center of civic life". Likewise, Durand et al. (2024) discuss the case for democratic planning to govern societal metabolism, limit environmental pressures and global inequalities and improve well-being.

Box 4: Opportunities for Economic Development through integrated policy responses

Integrated policy responses to the triple planetary crisis can generate economic and human development opportunities. Modelling of a "Sustainability Transition Scenario" in the Global Resources Outlook 2024 indicates that combining measures across resource efficiency, climate and energy, food and land, and social equity domains – rather than implementing policies in isolation – can decouple environmental pressures from economic growth while enhancing social outcomes (UNEP, 2024).

The Sustainability Transition scenario projects globally stronger economic growth, with the global economy 2,6% larger by 2060 compared to Hfistorical Trends. Resource-efficiency gains contribute most strongly to this uplift. Low- and lower middle-income countries benefit more, helping to narrow global economic inequalities. Human Development Index (HDI) outcomes improve across all income groups, with gains of up to 11,5% for low-income nations, indicating that economic growth can be accompanied by enhanced human well-being.

On a per capita basis, GDP per person more than doubles under the Sustainability Transition scenario between 2020 and 2060 – 109% growth compared to 100% under Historical Trends – demonstrating the potential for equitable and inclusive growth. In low- and lower middle-income

[3] Resource- and impact-intensive provisioning systems – built environment, mobility, food, and energy – account for about 90% of global material demand and are the dominant contributors to climate impacts, biodiversity loss, and water stress.

countries, these gains are particularly pronounced, facilitating convergence in income and productivity relative to higher-income countries. At the same time, high-income countries achieve reductions in per capita resource use and material footprints, highlighting the possibility of delivering growth while moderating environmental impacts.

However, the analysis does not incorporate the potential repercussions of environmental impacts – such as climate change, air and water pollution, or ecosystem collapse – on economic performance and human well-being. By its nature, economic and environmental modelling is a simplification of a complex reality, capable of illustrating potential trajectories but always subject to unknowns, omissions, and uncertainty.

In its latest flagship report on global resource use (UNEP, 2024), the International Resource Panel (IRP) models major shifts in resource use, energy, land, and equity using the IRP's integrated assessment framework (Sustainability Transition scenario). They project to 2060 that such measures can boost economic development and well-being while decoupling income from environmental impacts and reducing urgent ecological pressures. The analysis also finds "strong synergies between resource efficiency, greenhouse gas abatement and land use policies – with resource efficiency contributing to achieving climate mitigation while reducing the overall cost of combined policy ambitions". These outcomes, however, depend on significant changes to current provisioning systems, requiring strong, coordinated action from public and private sectors at unprecedented scale and speed. The report identifies six critical levers for this transition, which are outlined in the following sub-chapters:

- Institutionalizing resource governance and defining resource use pathways
- Redirecting finance toward sustainable resource flows
- Aligning trade with environmental goals
- Promoting sustainable consumption
- Supporting circular business models
- Improving provisioning system performance

2.4.1 Institutionalizing resource governance and defining resource-use paths

First, resource governance should be institutionalized at both global and national levels through monitoring, benchmarking, and integration into existing international environmental agreements (Bringezu et al., 2016). Thus, countries could make pledges for decoupling and incorporate consumption-based accounting into their climate commitments. Taking this idea forward would not need per se additional guidance from the international level, even though such pledges might benefit from the coherence through agreed structures and guidelines. The establishment of a dedicated International Materials Agency to coordinate a global sustainable resource management programme might also strengthen a global resource agenda (IRP, 2025a).

Second, coherent and ambitious global and national targets for resource use are needed to guide transitions. These should be context-specific, reflecting different income levels and consumption patterns, and linked to climate, biodiversity, land, and pollution objectives. Existing SDG indicators, planetary boundaries, and science-based target frameworks can inform such pathways (e.g. Fanning et al., 2022; Rockström et al., 2023; UNEP, 2024; Vélez-Henao and Pauliuk, 2023). Strengthening data and establishing an international resource-use database, potentially hosted by a global competence centre (e. g. the above-mentioned International Materials Agency), would improve transparency, monitoring, and policy development.

2.4.2 Redirecting finance toward sustainable resource flows

Aligning global finance with sustainable resource use requires transforming current systems that still incentivize unsustainable consumption, production, and unequal material flows. Key actions include internalizing environmental and social costs through measures such as taxes on virgin resource extraction, with revenues reinvested in SDGs and resource efficiency; phasing out and redirecting the US $1.25 trillion in harmful subsidies that currently support unsustainable practices in fossil fuel extraction and use, industrial agriculture, and fishing toward sustainable practices; and mobilizing private finance via a robust, measurable, and mandatory taxonomy for sustainable resource use aligned with climate and biodiversity goals. Financial regulators, along with central and multilateral development banks as well as sovereign wealth funds should further integrate climate, biodiversity, and resource-related risks into mandates and investment decisions, ensuring that capital flows support low-impact, resource-efficient pathways consistent with global sustainability objectives. Multilateral climate funds, including the Global Environmental Facility (GEF), the Green Climate Fund (GCF), the Adaptation Fund (AF) and the Climate Investment Funds (CIF) for instance already coordinate on methodologies through a Climate Funds Collaboration Platform (CFCP) (GEF, 2025) and on their approaches to transformational change (Chaplowe, 2025).

2.4.3 Aligning trade with environmental goals

High-income countries consume six times more materials than low-income countries, sustained by unequal trade that transfers raw materials, energy, and labour from poorer to richer nations at low prices, while offshoring environmental impacts and enabling capital flight from resource-rich regions (Hickel et al., 2022; Millward-Hopkins et al., 2025). This dynamic, compounded by financialized commodity markets and price volatility, undermines sustainable development in producer countries. To address these imbalances, trade governance reforms should internalize environmental and social costs, strengthen due diligence and sustainability provisions in trade agreements, regulate commodity markets, and implement impact-related border adjustment mechanisms. At the same time, producer countries can retain greater resource value through domestic refining, export restrictions on unprocessed materials, and local content policies – measures shown to support industrial development when paired with stable markets, policy coherence, realistic targets, and existing industrial capacity (IRP, 2025b). The question is to what extent such measures can realistically be pursued given pressures of international competitiveness, location-based competition, and the structural conditions of ecologically unequal exchange (Hickel et al., 2022).

2.4.4 Promoting sustainable production and consumption

All too often, the responsibility for sustainable consumption is placed solely on consumers. An analysis of German news from 2004-2018 shows that they often point the finger at consumers when discussing responsibility for pollution (Schönbauer and Müller, 2021), while producers and retailers are mainly absent. However, pollution occurs throughout the entire life cycle (Scientists' Coalition for an Effective Plastic Treaty, 2023), and e.g. for the case of plastic pollution, research shows that there is a direct link between plastic production and plastic pollution (Assefa-Aragaw et al., 2024; Baztan et al., 2024; Cowger et al., 2024; Olsen et al., 2025; Scientist's Coalition for an Effective Plastics Treaty, 2024). This is particularly important since economic gains are usually privatised (in the form of business profits), while economic losses (i.e. pollution) are usually borne by society.

When addressing sustainable consumption, it requires prioritizing high-income populations while ensuring fair consumption space – reducing excess in affluent contexts and enabling increased consumption where basic needs remain unmet (Otto et al., 2019; Vélez-Henao and Pauliuk, 2023). However, focusing solely on individual action is insufficient without systemic changes in infrastructure, regulation, and market signals. For example, national and regional action plans should target context-specific barriers and consumption hotspots, supported by improved data collection and analysis. Further key strategies include making sustainable goods and services affordable, disincentivizing high-impact products through regulation and pricing that reflects environmental costs, and "choice editing" to phase out unsustainable options. Raising awareness, regulating marketing that promotes overconsumption, mandating environmental footprint labelling, and combating greenwashing are essential to shift preferences toward sustainable alternatives. Tailored approaches are needed for different socioeconomic contexts, with attention to rebound effects and the disproportionate environmental impact of consumption behaviour by the wealthiest.

2.4.5 Supporting circular business models

Accelerating resource efficiency and CE adoption is essential to reduce primary resource demand and environmental impacts. Priority measures include scaling strategies such as eco-design, repair, reuse, remanufacturing, recycling, and sustainable biomass use, adapted to regional contexts and both production and demand sides. This requires robust monitoring and evaluation systems to assess effectiveness, prioritize actions, and mitigate rebound effects, with evidence pointing to high mitigation potential in industry, energy, and transport (Cantzler et al., 2020). Strengthened regulation on the national or supranational level (with common/harmonized policies) should set resource-efficiency and eco-design standards, promote industrial symbiosis, prevent landfill disposal of valuable materials, and extend producer responsibility, while incentivizing innovative business models like product-as-a-service. Building capacity, fostering skills, and supporting alliances and platforms can further scale up effective practices, integrate informal sector solutions, and enhance regional cooperation.

2.4.6 Improving provisioning system performance

Policy interventions that fail to consider resource use systemically risk unintended consequences and struggle to translate systemic visions into actionable plans. The concept of "provisioning systems" integrates ecological, technological, institutional, and social factors shaping how resources meet human needs. This perspective allows for a holistic understanding of resource use, revealing less resource-intensive ways to fulfill needs beyond conventional sector-specific solutions (Schaffartzik et al., 2021). For example, rather than focusing solely on expanding electric vehicle fleets – which demand high material inputs and infrastructure – provisioning systems encourage alternatives such as enhancing public transport, compact urban design, or remote working to reduce mobility demand. Four critical provisioning systems identified as resource-intensive yet vital to human well-being are energy, food, built environment, and mobility (see Table 1).

Table 1: Recommendations to achieve better performing resource-intensive provisioning systems

Provisioning System	Recommendation
Food	Reducing the demand of the most impactful food commodities
	Reducing food loss and food waste
	Protecting and restoring productive land while meeting demand for nutrition
Built Environment	Assuring sustainability of the new building stock
	Retrofitting the existing building stock
	More intensive use of buildings
	Decarbonizing material production
Mobility	Cities moving towards active mobility and public transportation
	Reducing carbon-intensive frequent travelling modalities
	Decreasing emissions intensity of transport modalities
Energy	Decarbonizing electricity supply through the scaling up of low-resource renewable energies and increased energy efficiency
	Decarbonizing fuels

Source: UNEP (2024). Own illustration.

3 Nature-based Solutions for a resilient planet

3.1 The role of NbS in addressing the triple crisis

Amid the triple crisis there is an urgent need for solutions that can address these challenges in an integrated way. NbS have emerged as one such approach and their multifunctional character positions them as a critical means of responding to interconnected global crises, enabling solutions that work with nature rather than against it.

NbS are defined as actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, resilience and biodiversity benefits (UNEA, 2022). They are increasingly recognized for their potential for climate change adaptation and disaster risk reduction (Kabisch et al., 2016), mitigate carbon emissions (Pan et al., 2023) and slow biodiversity loss and tackle pollution (Xie and Bulkeley, 2020). Beyond these specific contributions, NbS are now viewed as systemic interventions capable of tackling a much broader range of societal issues extending well beyond climate mitigation and adaptation or the reversal of biodiversity loss (Dunlop et al., 2024). According to the International Union for Conservation of Nature (IUCN), NbS can contribute to seven priority societal challenges that are central to addressing the triple crisis (IUCN, 2020)(see Box 5).

Box 5: Societal challenges addressed by NbS

- Climate change mitigation and adaptation
- Disaster risk reduction
- Economic and social development
- Human health
- Food security
- Water security
- Reversing environmental degradation and tackle biodiversity loss

Source: IUCN (2020).

By acting across these dimensions, NbS generate co-benefits that enhance their relevance in a time of converging crises (Hertig et al., 2023). By generating diverse benefits, NbS help sustain jobs in sectors such as small-scale fisheries and eco-tourism, improve agricultural productivity support public health and well-being, and increase resilience to food and water-related risks (Dunlop et al., 2024). Furthermore, when designed and implemented inclusively–through co-creation with affected communities and attention to equity, NbS can also reduce inequalities and ensure that their benefits are both effective and just (Kato-Huerta and Geneletti, 2022).

Building on this understanding of the role of NbS in addressing the triple crisis, the next section presents concrete examples of how NbS address the root causes of interconnected crises by preventing biodiversity loss, supporting climate change mitigation and adaptation, and reducing pollution and waste. This is followed by an analysis of the enabling conditions–such as governance, financing, and knowledge integration–that allow NbS to deliver these outcomes effectively, and a discussion of the challenges that must be addressed to unlock their full transformative potential.

3.2 Examples of Nature-based Solutions tackling the triple crisis

3.2.1 NbS for biodiversity loss prevention

Biodiversity loss, primarily driven by human activities such as land-use change, is eroding the natural systems that sustain life and increasing societal vulnerability. Its impacts span across ecological, economic, and public health domains, threatening food security, climate stability, and disease prevention. Healthy, biodiverse ecosystems underpin essential services, from pollination and soil fertility to carbon storage and water regulation, that are critical for human well-being. When biodiversity declines, these systems weaken: the loss of pollinators reduces crop yields and nutritional diversity, while degraded habitats lose their ability to buffer climate extremes and limit the spread of zoonotic diseases (Sharma and Birman, 2024).

NbS are increasingly recognized as powerful tools to tackle the drivers of biodiversity decline while delivering climate, economic, and social co-benefits (Burgos et al., 2024; Cohen-Shacham et al., 2016). They can be implemented across diverse landscapes, urban, peri-urban, and rural, helping to address interconnected societal and environmental challenges. By restoring and managing ecosystems, NbS reverse habitat degradation, improve ecological connectivity, and reduce pressures from unsustainable land use, which remain among the leading causes of biodiversity loss (Sharma and Birman, 2024).

For example, several urban NbS listed in Box 6 such as water retention ponds, and bioretention basins, manage stormwater while creating microhabitats for pollinators, amphibians, and other species and enhancing ecological connectivity across the city. Similarly, vertical greening solutions like green roofs, facades, and walls expand vegetated areas upward, providing nesting, foraging, and shelter opportunities for birds and insects, while contributing to urban cooling that supports heat-sensitive species (Iwaszuk et al., 2019). Taken together, the full range of measures in Box 4 deliver complementary benefits that help prevent biodiversity loss while enhancing urban resilience to climate and environmental pressures that are at the core of the triple crisis.

By integrating these NbS into urban planning, cities can transform impermeable, biodiversity-poor landscapes into networks of green and blue spaces that not only mitigate climate impacts but also reverse the trend of local species decline. This contributes to halting biodiversity loss while delivering co-benefits for human well-being, such as cleaner air, reduced heat stress, and improved access to nature.

Box 6: Urban Nbs and their benefits

► Water retention ponds	Provide cooling, CO_2 sequestration, pollutant removal, habitat creation, and public green space access
► Bioretention basins	Offer cooling, CO_2 sequestration, pollutant filtering, aesthetic design, and relatively low maintenance
► Bioswales	Reduce heat island effect and runoff, improve biodiversity, air quality, aesthetics, and recreational value
► Infiltration trenches	Support cooling, CO_2 capture, stormwater infiltration, flood resilience, and integrate well with other sustainable urban drainage systems (SUDS)

▶ Bioretention planters	Adaptable to tight urban spaces, retain stormwater, improve aesthetics, and support infiltration
▶ Green bus stops	Mitigate flooding, reduce heat island effect, enhance biodiversity, and create green public transport shelters
▶ Green roofs	Cool microclimate, insulate buildings, retain rainwater, better air quality, carbon capture, and social amenity
▶ Green facades and walls	Provide temperature control, thermal insulation, improved air quality, UV protection, noise insulation, and biodiversity habitat

Source: Based on Addressing Climate Change in Cities – Catalogue of Urban Nature-Based Solutions (Iwaszuk et al., 2019).

In rural contexts, NbS address the root causes of biodiversity loss by rehabilitating degraded habitats, restoring ecological connectivity, and integrating biodiversity into productive landscapes (CFS, 2014). As outlined by Simelton et al. (2021), rural NbS can be grouped into four broad categories–sustainable production systems, green and blue infrastructure, amelioration measures, and conservation actions–each providing distinct ecological, economic, and social benefits (See Table 2).

Large-scale interventions, such as reforestation, wetland rehabilitation, and peatland rewetting, help reinstate natural processes that sustain species diversity and ecosystem stability. Ecological corridors, including riparian buffer zones, hedgerow networks, and wildlife-friendly field margins, facilitate species movement and genetic exchange (Simelton et al., 2021). These measures are most effective when paired with actions that reduce pressures on land, such as shifts in agricultural practices, dietary patterns, and food systems, to avoid land-use conflicts (WWF, 2020).

Table 2: Categories of rural NbS and their benefits

Category	Primary purpose	Examples	Key benefits
Sustainable production systems	Production with biodiversity integration and natural nutrient/microclimate management	Agroforestry, windbreaks, diversified cropping	Enhanced soil health, stable yields, safeguarded livelihoods, reduced temperature stress impacts
Green infrastructure	Physical regulation of water and soil; slope stabilisation	Grass strips, hedgerows, terraces with natural materials	Reduced erosion, prevention of mass movement damage, additional fodder supply
Amelioration measures	Restoration of plant, water, soil, or air quality; climate mitigation	Bio-/phytoremediation, mangrove restoration	Safe water, reduced health risks from pests, carbon sequestration
Conservation actions	Maintenance or increase of ecological health at field/landscape scales	Natural fallow, assisted regeneration	Safeguarded biodiversity, cultural and spiritual values, nutrient cycling, resilience to environmental stress

Source: Adapted from Simelton et al. (2021).

Sustainable agriculture represents a pivotal NbS pathway, integrating biodiversity into farming systems while maintaining productivity. Approaches such as agroecology, agroforestry, regenerative farming, and syntropic agriculture improve soil health, support pollination and pest regulation, and increase resilience to climate change (GIZ, 2020). Scaling up these practices, alongside targeted measures can make rural landscapes active drivers of biodiversity recovery, climate mitigation, and livelihood security (Simelton et al., 2021). By simultaneously protecting biodiversity, enhancing climate resilience, and supporting livelihoods, these solutions directly address the interlinked crises of biodiversity loss, climate change, and social vulnerability at the heart of the triple crisis.

3.2.2 NbS for climate adaptation and mitigation

NbS for climate change can be defined as: "ecosystem conservation, management and/or restoration interventions intentionally planned to deliver measurable positive climate adaptation and/or mitigation benefits that have human development and biodiversity co-benefits managing anticipated climate risks to nature that can undermine their long-term effectiveness." (WWF, 2020, p. 3).

NbS can make a significant contribution to reducing greenhouse gas emissions, with global technical potential estimated at around 5 $GtCO_2e$ annually by 2030 and up to 10 $GtCO_2e$ annually by 2050, even under conservative scenarios (UNEP and IUCN, 2021). This potential spans a diversity of ecosystems, with the largest overall mitigation opportunities in forests, followed by grasslands and agricultural systems, while peatlands and coastal wetlands offer exceptionally high carbon storage per hectare despite their smaller total area (UNEP and IUCN, 2021). Since building up new carbon stocks through restoration takes many years to decades, protecting existing carbon-rich ecosystems is crucial to avoid immediate and substantial greenhouse gas releases from degradation or conversion (UNEP and IUCN, 2021).

Mitigation-focused NbS include the conservation, restoration, and sustainable management of carbon-rich ecosystems. Blue carbon systems, such as mangroves, seagrasses, and salt marshes, play a crucial role in mitigating climate change. They sequester vast amounts of carbon while also providing coastal protection and biodiversity protection by providing habitats to a wide range of marine species. Reforestation and afforestation, when applied as a NbS supporting ecosystem restoration, can deliver multiple benefits, including increased biomass carbon storage, soil restoration, and improved water cycles. To ensure effectiveness and legitimacy, these interventions should be co-designed with local communities and tailored to specific local contexts. Robust environmental and social safeguards are essential for all NbS interventions, and are particularly critical for large-scale projects, to guarantee genuine climate benefits, prevent harm to people and ecosystems, and avoid the misuse of the NbS concept for greenwashing. The scientific community has developed standards and guidelines to help governments and institutions minimize these risks and promote credible, responsible implementation. For example, the IUCN Global Standard for NbS, serves as a framework for the coherent design, implementation, and evaluation of NbS, and comprises right specific criteria and 28 indicators (IUCN, 2020). If developed carefully and thoroughly, safeguards can help guarantee biodiversity gains, protect the rights and livelihoods of local and Indigenous communities, prevent risks such as land-use conflicts or monoculture plantations, and uphold the integrity of climate outcomes by addressing leakage, permanence, additionality, and double counting. Without such safeguards, NbS risk losing legitimacy and may undermine both climate and biodiversity goals (UNEP and IUCN, 2021).

In agricultural landscapes, practices such as agroforestry, cover cropping, and reduced tillage maintain soil fertility, limit emissions from land-use change, and provide livelihood benefits (Simelton et al., 2021).

However, NbS can only deliver their full mitigation potential if implemented alongside rapid and sustained reductions in fossil fuel and industrial emissions. Without ambitious decarbonization efforts, climate change could impair the carbon storage capacity of ecosystems, risking a shift from net sinks to net sources of greenhouse gases (Pörtner et al., 2021; Seymour and Langer, 2021).

NbS also deliver critical climate adaptation benefits by enhancing the natural protective functions of ecosystems. Urban NbS, such as green roofs, tree canopies, and permeable surfaces, lower urban heat island effects, improve stormwater infiltration, and create cooler microclimates–reducing heat stress and flood risk for vulnerable populations (Kabisch et al., 2017). In coastal zones, mangroves buffer communities from sea-level rise and storm surges by trapping sediments, building shoreline elevation, and dissipating wave energy. Such measures, rooted in the protection, sustainable management, and restoration of natural or modified ecosystems, can simultaneously safeguard biodiversity and human well-being (Johnson et al., 2022).

Importantly, NbS deliver these adaptation benefits while maintaining or enhancing ecosystem services that underpin food and water security. By integrating NbS into long-term adaptation strategies, governments and communities can reduce exposure to hazards, strengthen ecosystem resilience, and support sustainable livelihoods–providing a cost-effective complement to engineered infrastructure (Johnson et al., 2022).

Box 7: Penang Community Mangrove Conservation – A Dual Adaptation & Mitigation NbS

- **Summary**: This community-led initiative in Penang, Malaysia rehabilitated degraded mangrove forests by planting approximately 11,000 saplings across 3 km², supported by the Penang Inshore Fishermen Welfare Association (PIFWA) and the Global Environment Facility. The project aimed to restore coastal ecosystems, foster biodiversity, and bolster local livelihoods through environmental education and active participation.
- **Climate Adaptation benefits**: Coastal Protection: Mangroves stabilize shorelines and reduce erosion, acting as natural buffers against waves and storm surges, thereby enhancing resilience to sea-level rise and extreme weather.
- **Climate mitigation benefits**: Carbon Sequestration: Through restoration of mangrove ecosystems, the project enhances carbon storage in biomass and sediment, contributing to long-term carbon removal.
- **Additional co-benefits**: Protects biodiversity by providing habitat for marine and terrestrial species. Supports livelihoods of coastal fisheries dependent on healthy mangrove ecosystems.

Source: Urban Nature Atlas (2024).

3.2.3 Pollution reduction through NbS

Ecosystems can function as natural filters for pollutants, reducing pressures on biodiversity and human health while delivering climate and social co-benefits. By restoring and enhancing these functions, NbS address one of the key dimensions of the triple crisis–pollution–through low-tech, ecosystem-based solutions for water purification, soil remediation, and air quality improvement (Biswal et al., 2022).

NbS such as constructed wetlands, green roofs, and bioretention systems are widely applied to remove nutrients, organic pollutants, heavy metals, and even pharmaceuticals from stormwater, with relatively low cost and minimal energy demand. These systems are increasingly integrated into urban drainage networks, reducing flash-flood risk while providing habitat and improving water availability in water-scarce cities (Biswal et al., 2022). Roadside vegetation, hedgerows, and mixed tree–shrub plantings can capture particulate matter ($PM_{2.5}$ and PM_{10}) and gaseous pollutants by adsorption to leaf and branch surfaces, metabolizing them into less harmful forms or dispersing polluted air through physical barriers (Biswal et al., 2022).

Table 3: Examples of NbS for pollution mitigation in urban areas

NbS type	Main function	Pollution target	Additional co-benefits
Constructed wetlands	Removal of stormwater pollutants	Heavy metals, nitrogen, phosphorus, suspended solids	Mitigating urban heat island effects, reducing noise pollution, enhancing biodiversity, environmental aesthetics
Bioretention systems (rain gardens)	Manage stormwater runoff; reduce peak flow and flooding	Sediments, nitrogen and phosphorus, heavy metals, organic micropollutants (PAHs, PCBs)	Improving air quality improvement, enhancing biodiversity, water conservation
Green roofs	Capture and slow rainfall, filter runoff	Removes particulate matter, nutrients	Urban cooling, insulation, biodiversity support
Roadside vegetation / vegetation barriers	Intercept airborne pollutants	Captures $PM_{2.5}$, PM_{10}, NO_2	Noise reduction, shading, ecological connectivity
Urban trees and parks	Improve air quality, microclimate	Uptake of gaseous pollutants, PM	Recreational space, psychological well-being

Source: Adapted from Biswal et al. (2022).

Beyond pollution control, urban greenery supports mental and physical health, promotes beneficial microbiome exposure, reduces noise, and enhances recreational and aesthetic values (Iwaszuk et al., 2019). When designed to be multifunctional, locally adapted, and connected across the urban landscape, these NbS can help cities simultaneously tackle pollution, biodiversity loss, and climate impacts.

Box 8: Community driven initiative in Cartagena Colombia

- **Summary**: This community-driven initiative in the Boston neighborhood of Cartagena, Colombia, was coordinated by the Public Environmental Establishment (EPA Cartagena) in partnership with local leaders, public agencies, private companies, and NGOs. Located adjacent to the Ciénaga de la Virgen coastal wetland–a key biodiversity area impacted by wastewater and solid waste–the project combined mangrove restoration, solid waste and plastic removal, and environmental education. Activities included rehabilitating degraded mangrove areas, organizing clean-up campaigns, creating recreational green spaces, and conducting awareness sessions on sustainable water and energy use.

- **Climate adaptation benefits**: Flood and coastal protection: Restored mangroves buffer the community from storm surges, reduce flood risk, and stabilise shorelines.
- **Climate mitigation benefits**: Carbon sequestration: Mangrove restoration increases carbon storage in biomass and sediment, contributing to long-term climate mitigation.
- **Additional co-benefits**: Improved local biodiversity by providing habitat for wetland and marine species. Enhances community well-being through greener public spaces and recreational areas. Strengthens environmental stewardship via participatory governance and education.

Source: Urban Nature Atlas (2025).

3.3 Key considerations on NbS enabling conditions and challenges

For NbS to deliver on their full potential in addressing biodiversity loss, climate change, and pollution, they must be supported by coherent enabling conditions that cut across policy, finance, governance, and knowledge systems.

- **Policy coherence:** By strategically adopting policy instruments across different decision-making scales and crafting comprehensive policy mixes, obstacles in pathways to urban NbS mainstreaming can be overcome and NbS are not going to be implemented in isolation but integrated into broader sustainability agendas (Van Der Jagt et al., 2023). This means, for example, embedding NbS into National Biodiversity Strategies and Action Plans (NBSAPs), climate adaptation and mitigation strategies, and urban planning frameworks. In practice, city development plans should explicitly recognize the role of nature for health, climate protection, biodiversity, and pollution reduction (Kozban et al., 2023). Yet, evidence shows that biodiversity objectives are still underrepresented: in a review of 976 urban NbS projects in Europe, only one-third explicitly included biodiversity goals, often focusing on ecosystem-level outcomes such as integrity and connectivity rather than on species or genetic diversity (Xie and Bulkeley, 2020). Strengthening policy coherence across biodiversity, climate, and pollution domains is therefore essential for NbS to address the triple crisis.
- **Financing NbS** is a second enabling condition and a persistent challenge. Despite growing attention to NbS and their potential as a systemic solution, when it comes to financing them there remains a lack of priority, clear standards, and institutional recognition (McCormick et al., 2024). Developing and maintaining urban nature, from wetlands and parks to green roofs and facades, requires diverse instruments tailored to ownership structures and life cycles. Capital investment is essential, but so is the willingness of financial institutions to engage and the capacity of decision-makers to integrate nature into financial planning. Because NbS generate public goods, they do not always fit conventional economic models. A few sustainable banks and development institutions are leading positive investment in nature, but private finance still views returns as non-negotiable, limiting large-scale uptake (McCormick et al., 2024).

  A major challenge is the lack of robust indicators to demonstrate benefits such as climate resilience, which often manifest only over long timeframes and remain undervalued in financial risk models (McCormick et al., 2024). Maintenance is another weak point: without clear models to sustain assets, initial investments in NbS may quickly degrade. Community-based projects, meanwhile, demand long-term funder commitment that goes beyond short-term financial returns. Still, opportunities exist. Stronger articulation of NbS co-benefits–for example, avoided costs from climate impacts, reduced health burdens from pollution, and biodiversity recovery - could make the case for investment more compelling. Innovative business models that combine economic returns with public value will be critical for unlocking the potential of NbS (McCormick et al., 2024).

- A third, related enabling condition is **long-term, predictable financing with safeguards**. Large-scale NbS require investment frameworks that also protect communities and ecosystems. Initiatives such as the LEAF Coalition and the Green Gigaton Challenge demonstrate how new finance can be mobilised for forests, but similar mechanisms are needed for peatlands, agricultural lands, and coastal ecosystems (UNEP and IUCN, 2021).
- **Inclusive and equitable governance** forms a fourth enabling condition. NbS are most effective when designed and implemented *with and for people* (Seddon et al., 2021). Meaningful participation of local communities, municipalities, and Indigenous Peoples enhances legitimacy and outcomes, while top-down approaches risk alienation and weaker long-term results (Kozban et al., 2023). Meaningful and comprehensive participation entails the intentional inclusion of civil society through trust-building, flexible and culturally sensitive processes that ensure equity, recognition, and method diversity, while fostering shared expectations and continuous learning so that communities are genuinely engaged as co-creators rather than passive beneficiaries (Davis et al., 2025). One approach of ensuring that NbS meet specific local requirements and incorporate culturally rooted practices is to design a co-creative process involving relevant stakeholder groups and integrating the diverse knowledge systems held across the region in the NbS planning processes (Burgos et al., 2024). Processes of knowledge co-production that integrate scientific, local, and traditional knowledge are essential to ensure context-specific solutions. However, participation is not automatically transformative. As Hafferty et al. (2025) warn, participatory processes can sometimes mask deeper power dynamics, resulting in "democracy washing" . To avoid this, NbS governance must emphasize transparency, accountability, and empowerment, with attention to equity and justice.
- Finally, **adaptive governance under conditions of uncertainty** is essential. Many sustainability challenges involve trade-offs among competing priorities and values that cannot be solved by technical fixes alone. The outcomes of NbS interventions are often unpredictable, and their value differs across stakeholder perspectives (Hafferty et al., 2025). Enabling conditions must therefore include flexibility in planning, space for negotiation, and the ability to adapt governance to shifting risks, knowledge, and societal needs.

4 Systemic change and transformation

4.1 Systemic transformation: The foundation for addressing the triple planetary crisis

As outlined in the report on "The Interconnected Challenges of Climate Change, Biodiversity Loss and Environmental Pollution – Drivers, Interdependencies and Impacts of the Triple Planetary Crisis" (Knoblauch et al., 2025), our world is facing multiple, globally interconnected crises, which are driven by a shared set of root causes such as fossil fuel dependence, unsustainable resource use, and entrenched structural inequalities (IPBES, 2024; IPCC, 2023; UNEP-ISC, 2024). These underlying drivers are largely controlled by a small number of powerful actors whose consumption patterns and resource use disproportionately fuel biodiversity loss, climate change, and pollution (IPBES, 2024). The resulting impacts fall most heavily on the most affected people and areas (MAPA), including Indigenous Peoples and local communities, who often have the least access to decision-making and the fewest resources to adapt (UNDP, 2024).

Tackling these globally interconnected crises thus requires *transformative change* of the entire system to tackle the underlying root causes and structures. Although there is no universal definition of transformative change, it commonly refers to a radical change, as opposed to incremental changes, leading to a fundamental shift in the status quo of the current system and across views, structures, and practices (see Box 9) (IPBES, 2019a, 2024; Korhonen-Kurki et al., 2025). Incremental or isolated measures are insufficient to address these converging crises. The same systemic drivers, including land-use change, overexploitation of resources, pollution, and social inequity, cut across climate, biodiversity, and pollution challenges, creating reinforcing feedback loops and cascading risks (IPBES, 2024). For example, biodiversity loss can reduce ecosystem resilience to climate extremes, while climate change accelerates species decline and pollution further degrades ecosystem function (Pörtner et al., 2023).These interactions amplify the scale and speed of harm to both ecosystems and societies.

Box 9: Transformative Change

IPBES defines transformative change for a just and sustainable world as *"a fundamental, system-wide reorganization across technological, economic and social factors, including paradigms, goals and values"* (IPBES, 2019b). The fundamental, system-wide shift in views, structures, and practices should be guided by four principles: i) equity and justice; ii) pluralism and inclusion; iii) respectful and reciprocal human-nature relationships; and iv) adaptive learning and action (IPBES, 2024).

As the triple planetary crisis is underpinned by shared drivers and cross-cutting risks, transformative change cannot be achieved by single actors or siloed policies alone. Synergies across policy domains, governance levels, and sectors act as an enabler of transformation, ensuring that actions targeting one crisis do not undermine, but instead accelerate, progress in others. Building such synergies also provides a practical pathway for transformation, as they help pool resources, align governance frameworks, and mobilise innovation across domains, thereby overcoming fragmentation and the inefficiencies of incremental responses (UN, 2024). At the same time, synergies are a means of ensuring justice which, when designed inclusively, ensure that efforts to overcome one crisis do not exacerbate inequalities in another crisis, but instead bring mutual benefits to people and ecosystems, especially those most affected (IPBES, 2024).

At both EU and international levels, multiple initiatives are already seeking to operationalise such synergies in practice. Globally, the Rio Conventions have established collaborative mechanisms such as the Joint Liaison Group of the Secretariats of the three Conventions and the Joint Capacity-building Programme, which aim to strengthen coordination and capacities across climate action, biodiversity conservation, and sustainable land management, directly linking to the achievement of the SDGs (CBD, 2025). At the same time, Parties to the UNFCCC and the Paris Agreement are discussing advancing transformative agendas through work such as the Just Transition Work Programme and the extended Enhanced Lima Work Programme on Gender, while the UN Secretary-General has called for "transformative progress" across key systems including energy, food, social protection, and education to meet the goals and targets of the Paris Agreement and Agenda 2030. Scientific and intergovernmental bodies reinforce this call: the IPCC urges deep structural transformations across energy, industry, transport, and land use systems (IPCC, 2022), while the IPBES Transformative Change Report stresses the urgency of shifting human–nature relations to halt biodiversity loss (IPBES, 2024). It is estimated that achieving six transformative pathways outlined in the Global Sustainable Development Report 2023 would require investments of USD 5.4–6.4 trillion annually by 2030 (UN, 2024), significant but far less than the costs of inaction. Similarly, synergies are increasingly being leveraged between the Rio Conventions and the Paris Agreement, with the UNCCD emphasising the benefits of aligning biodiversity and land degradation agendas (UNCCD, 2023; UNDCC, 2024). The synergies are at this stage still largely discussed under the CBD and the UNCCD but discussions under the UNFCCC have picked up the topic in 2025 as well (under the negotiation item on "Cooperation with other International Organizations"). Collectively, these strategies demonstrate that addressing the triple planetary crisis requires coordinated, systemic, and transformative action across scales, sectors, and institutions, moving decisively beyond incremental approaches.

Transformative change is complex, and the variables discussed here represent only a fraction of what is required to unlock deep, systemic transformation. Achieving a just and sustainable world demands action across three interwoven dimensions outlined in the following chapter 4.2:

- ***Shifting* views:** rethinking how we see and value nature
- ***Reshaping* systems and practices:** reforming governance, markets, and consumption patterns; and
- ***Restoring* places that matter:** co-managing conservation and regeneration.

Transformation depends on coordinated shifts across all three dimensions. Cultural and value shifts can create political space for governance reforms, restructured institutions and economic incentives can enable sustainable practices, and the adoption of these practices at scale can, in turn, reinforce new societal values. Justice is central to this process. As IPBES underscores, MAPA must be recognized not only as vulnerable groups but also as active agents of change whose knowledge, rights, and agency are integral to designing and implementing effective and just solutions. It requires context-specific analysis to determine the level and degree of involvement for local, national and international approaches.

4.2 Unfolding transformative change

4.2.1 Shifting views: Rethinking how we see and value nature

The way societies see, and value nature fundamentally shapes how they interact with it. As laid out in the IPBES Transformative Change Assessment (2024), *views* are a core dimension of systemic transformation, encompassing the world views, cultural narratives, and knowledge systems that influence decision-making. In many dominant paradigms, nature is still treated primarily as an external resource to be exploited for economic gain. This perspective reinforces the disconnection between people and ecosystems, undermining ecological integrity and driving the interconnected crises of climate change, biodiversity loss, and pollution.

Transforming these views requires broadening our collective understanding of nature's multiple values, its intrinsic worth beyond human use, its instrumental role in sustaining human societies, and its relational value as the foundation of cultural identity and community well-being. Recognizing this diversity of values can reorient policy, investment, and everyday practices towards sustainability and equity. Embedding ecological literacy and sustainability principles in education systems, public discourse, and policymaking is essential for reframing nature not merely as a resource, but as the basis of life and well-being.

Re-establishing human-nature relationships

Re-establishing human–nature relationships is central to systemic transformation for addressing the triple planetary crisis. Disconnection from nature has been identified as a root cause of biodiversity loss, environmental degradation, and the erosion of cultural and social fabrics. Strengthening nature connectedness fosters care, responsibility, and pro-environmental behaviour while enhancing human wellbeing and resilience (IPBES, 2024). Recent advances in psychology highlight that nature connectedness functions like a genuine relationship, shaped by quality, meaningful engagement with the natural world, and linked to self-transcendence and identity formation (Lengieza and Aviste, 2025). At the same time, relational environmental values, defined as valuing nature because of the relationships that emerge between people and ecosystems, are emerging as powerful, distinct predictors of pro-environmental intentions and behaviours, often stronger than intrinsic or instrumental values. Together, these insights underline the importance of not only increasing opportunities for meaningful encounters with nature through education, community initiatives, and cultural practices, but also cultivating relational value systems that recognize interdependence and reciprocity between people and the more-than-human world, as reflected in Indigenous worldviews such as that of the Aka Hrusso community (D'Souza, 2025) (see Box 10). Such approaches are actionable across diverse domains, urban planning, healthcare, education, and child development, and hold potential to re-establish human–nature relations as a foundation for transformative change.

Box 10: Aka Hrusso of Arunachal Pradesh (India)

The Aka Hrusso of Arunachal Pradesh (India) understand nature as a sentient, agentive community of beings with whom humans share kinship and reciprocal obligations. Their worldview embraces both care and awe, love and fear, recognising nature's nurturing qualities as well as its unpredictable power. Through stories, rituals, and practices of reciprocity, they embody a relational paradigm in which human wellbeing depends on maintaining harmony with spirits, animals, plants, and the land itself (D'Souza, 2025).

Knowledge co-creation and diverse knowledge systems

Transformative change encompasses the integration of diverse knowledge systems, including Indigenous and local knowledge, as they provide powerful illustrations of alternative worldviews rooted in stewardship, reciprocity, and care. Indigenous Peoples and local communities have different perspectives, and their practices and lifestyles are often rooted in knowledge and value systems that are associated with positive social, economic and environmental outcomes (IPBES, 2024). Intertwining insights from diverse approaches and knowledge systems in governance approaches to tackle planetary crises, can thus enhance effective and legitimate transformation.

The essential role of Indigenous knowledge and practices in conservation is underscored by the fact that the areas of highest biodiversity on the planet are under Indigenous stewardship. While accounting for only a small share of the global population, Indigenous Peoples and local communities steward over one third of the planet's most critical biodiversity areas, and 42 percent of their lands are maintained in good ecological condition, highlighting the effectiveness of their conservation practices (UNEP-WCMC, 2023). Indigenous, local, and traditional knowledge systems have also shown to be vital resources for adapting to climate change and addressing land degradation, yet they remain inconsistently applied in current adaptation efforts, even though their integration with scientific and policy approaches enhances the overall effectiveness of responses (IPCC, 2019).

Collaborations between Indigenous knowledge holders and scientists have generated novel insights into interactions between people and nature, providing new understandings that would not have been achieved by either system alone, and resulting in diverse and context-specific conservation outcomes (Wheeler and Root-Bernstein, 2020). The SmartICE Inuit Youth Training Programme in Inuit Nunangat, Canada (see Box 11), illustrates how co-created approaches can integrate traditional knowledge and advanced technologies, empower youth as leaders in climate adaptation, and strengthen cultural identity and self-determination in resource governance.

Box 11: SmartICE Inuit Youth Training Programme (Canada)

The SmartICE Inuit Youth Training initiative in Inuit *Nunangat* (Canada) empowers Inuit communities by blending Inuit *Qaujimajatuqangit* (traditional Inuit knowledge) with advanced technology, like SmartBUOYS, satellite mapping, and SmartQAMUTIK sled sensors, to produce real-time sea-ice maps and safer travel information (CJRF, 2021). Inuit youth are trained in assembling these monitoring devices and co-designing culturally grounded, locally relevant adaptation tools, strengthening both technical skills and cultural identity (SmartICE, 2022). This approach enables systemic transformation by fostering youth leadership, reinforcing Inuit knowledge and language, and promoting self-determination in climate adaptation decisions.

However, long-standing power asymmetries have often excluded Indigenous and marginalized communities from environmental governance. Colonial histories have dispossessed many of their lands, undermined livelihoods, and ignored values and knowledge in pursuit of economic growth, and even modern conservation models sometimes reproduce these injustices by prioritizing climate or biodiversity goals without fully considering local rights and needs (Kozban et al., 2023). These dynamics persist even though many such communities have contributed least to environmental degradation and are among the most vulnerable to its impacts. Addressing these inequities is essential as differences in epistemologies, power imbalances, and risks of marginalization can hinder collaboration, making equitable partnerships, co-production of knowledge, and respect for Indigenous sovereignty crucial to realizing the full potential of weaving knowledge systems for transformative change (Wheeler and Root-Bernstein, 2020).

4.2.2 Reshaping systems and practices: reforming governance, markets, and consumption patterns

Transforming Economic Systems for Nature and Equity

Transforming economic systems is essential to align financial flows with sustainability and address the structural drivers of nature and biodiversity loss. Current financial institutions often reinforce inequities and prioritize short-term private gains, creating barriers to transformative change (IPBES, 2024). Reforming incentives and financial systems can redirect resources towards sustainable production and conservation, for example through payments for ecosystem services, subsidies, and fiscal reforms that reward biodiversity-friendly practices. Debt-for-nature swaps are a promising mechanism, particularly in low- and middle-income countries, as shown by the Galápagos marine debt swap in Ecuador (see Box 12), where debt relief was channelled into long-term conservation finance.

Box 12: Galápagos Marine Debt Conversion (Ecuador)

In May 2023, Ecuador executed the world's largest debt-for-nature conversion, exchanging approximately US $1.63 billion of commercial debt for a US $656 million blue loan, backed by guarantees and insurance. The deal provides over US $450 million for long-term marine conservation via the Galápagos Life Fund (GLF) (Pew, 2023). This structural innovation redirected fiscal resources into a protected marine ecosystem, institutionalizing conservation finance and establishing an endowment that provides roughly US $12 million annually in perpetuity (Pew Bertarelli Ocean Legacy, 2025). The arrangement represents a novel financing mechanism that embeds conservation funding structurally into national debt management frameworks. Nevertheless, concerns have been raised about governance and legitimacy, as the GLF is registered offshore its governance structure grants real control to foreign investors and private organizations, while the Ecuadorian state holds only a minority presence (CFFA, 2025). Moreover, civil society groups argue the process lacked transparency, sufficient local and indigenous stakeholder participation as well as prior consultation (CFFA, 2025).

At the systemic level, a transition to a nature-positive economy goes beyond reducing harm to actively enhancing ecosystems through restoration and regeneration, including NbS. This vision emphasises job creation, innovation and resilience as co-benefits of investing in nature, while requiring binding commitments, adequate funding, and stronger accountability to overcome harmful subsidies and greenwashing (Kupilas et al., 2025). Embedding nature into the core of financial regulation, business practices, and policy frameworks is critical to decouple economic development from environmental degradation. By linking ecological restoration, sustainable production, and social wellbeing, nature-positive economies can align solutions for interconnected crises of climate, biodiversity, and pollution with a broader agenda of equity and regeneration. Achieving this vision requires systemic change to create an enabling environment for an economy that restores nature and supports people, while embedding sustainability more consistently across regulatory, economic, and governance frameworks (Kupilas et al., 2025).

Transforming Governance Systems to be Integrated, Inclusive, and Adaptive

Effective governance is at the heart of transformative change, yet no single governance model can fully capture the complexity of sustainability transitions. A growing body of literature highlights approaches such as adaptive, earth system, evolutionary, transition, and transformative governance, each offering distinct yet complementary insights into managing socio-ecological challenges (Jansen and Kalas, 2020). While adaptive and evolutionary governance emphasizes learning, flexibility, and adaptation over time, earth system and transition governance take a broader, structural view of global interdependencies and systemic shifts. In contrast, transformative governance focuses explicitly on enabling fundamental, systemic change and addressing entrenched power relations, often through inclusive, multi-level, and cross-sectoral approaches (Korhonen-Kurki et al., 2025). Across all approaches, collaboration, leadership, learning, plurality, empowerment, innovation, and vision emerge as key mechanisms for fostering sustainability transformations.

An illustrative example of transformative governance in practice is the land reform process in South Africa (see Box 13). This process demonstrates how broad participation, dialogue, and shared ownership can help overcome historic injustices, strengthen legitimacy, and lay the foundations for systemic transformation in land governance (Jansen and Kalas, 2020).

Box 13: Multi-Stakeholder Transformative Governance (South Africa)

In South Africa, land reform has long been central to addressing deep inequalities rooted in apartheid-era dispossession. To advance this process, a national multi-stakeholder platform was established with government, civil society, academia, and private sector actors co-chairing the effort. Anchored in the FAO's Voluntary Guidelines on the Responsible Governance of Tenure, this country-driven, bottom-up partnership created a space for inclusive dialogue, trust-building, and joint decision-making. By combining diverse perspectives and ensuring deliberative capacity, the process moved beyond top-down policy to collective ownership of reform pathways. While challenges remain, the South African case highlights how multi-stakeholder transformative governance can increase legitimacy, reduce conflict, and enhance the potential for lasting systemic change in land tenure and beyond (Jansen and Kalas, 2020).

Shifting Consumption Patterns and Decoupling Well-being from Resource Use

Unsustainable production and consumption patterns are major drivers of biodiversity loss, climate change, and pollution, yet they are reinforced by structural lock-ins in political, economic, and institutional systems (IPBES, 2024). Reforming harmful subsidies for fossil fuels and industrial agriculture, and redirecting them towards sustainable practices, is one of the most powerful levers for change (IPBES, 2024; Kupilas et al., 2025). Embedding planetary boundaries and equity into planning systems is critical to ensure that economic activity remains within a safe and just operating space for humanity (Richardson et al., 2023).

The idea of *decoupling*, i.e. achieving economic growth while reducing resource use and environmental impacts, remains central to sustainability discourse. A key distinction is between *relative* decoupling, where resource use or emissions grow more slowly than GDP, and *absolute* decoupling, where they decline in absolute terms despite GDP growth (Haberl et al., 2019). While relative decoupling has been observed in many countries for material use and emissions, examples of long-term absolute decoupling remain rare and often limited in scope. Globally, no significant absolute decoupling of resource use or environmental impacts occurred from 2015 to 2023 (Parrique et al., 2019; UNEP, 2024). This calls into question the viability of current green growth strategies and reinforces the need for sufficiency, i.e. reducing consumption, scaling down material throughput, and embracing social innovation over purely technical fixes, while addressing structural barriers and lock-ins. The International Resource Panel reflects this by introducing the concept of *double* decoupling, which refers to the concept of decoupling human well-being from resource use, as well as resource use from environmental impacts and by advocating metrics of success that go beyond GDP (Haberl et al., 2020; UNEP, 2024).

4.2.3 Restoring places that matter: Co-managing conservation and regeneration

Co-management and Regenerative Practices

Conserving and regenerating places of value to nature and people requires approaches that move beyond extractive and top-down conservation models toward co-management and regenerative practices. As IPBES (2024) highlights, conservation and regeneration are embedded in a relational paradigm that emphasizes the entanglement of natures and cultures, intergenerational responsibilities, and the recognition of Indigenous and local knowledge. This perspective reframes conservation not as humans acting on nature, but as co-evolving with nature, regenerating both ecosystems and cultural practices simultaneously.

A cornerstone of this approach is the recognition of *territories of life*, i.e. landscapes and seascapes stewarded by Indigenous Peoples and local communities, which are often vital to maintaining biocultural diversity. Indigenous Peoples manage or have tenure rights to roughly 40% of protected areas and intact landscapes worldwide, and their stewardship under customary governance has been shown to deliver positive ecological and social outcomes (IPBES, 2024). Effective co-management requires not only recognition of these rights but also legal protections, equitable power-sharing, and governance in ethical spaces that embrace multiple ways of knowing.

A practical example comes from Hawaiʻi (see Box 14), where co-managed marine zones integrate Indigenous Hawaiian knowledge with state governance. Grounded in stewardship, reciprocity, and care, this community-driven approach has led to rebounding fish stocks, regenerating ecosystems, and reinforced cultural values. IPBES (2024) stresses that the inclusion of Indigenous and local knowledge systems in governance is critical for effective and legitimate transformation, and the Hāʻena case illustrates how co-created programs that combine traditional ecological knowledge with restoration efforts can restore ecological functions while strengthening cultural identity and social resilience. This highlights the transformative potential of regenerative conservation when rooted in inclusive governance and relational values.

Box 14: Co-Managing Marine Resources (Hawai'i)

The Hāʻena Community-Based Subsistence Fishing Area in Kauaʻi, Hawaiʻi, is a co-managed marine zone led by the Hāʻena community together with the State's Department of Land and Natural Resources, established in 2015 to support sustainable, culturally grounded subsistence fishing under customized harvest and gear rules (Rodgers et al., 2021). Five-year evaluations (2016-2020) by the University of Hawaiʻi and state partners report positive ecological outcomes, such as increased biomass and density of culturally valued fish species, alongside strengthened community stewardship (Hiraishi, 2023). These improvements demonstrate how integrating Indigenous knowledge, local governance, and scientific monitoring can drive transformative, place based resource management.

Recognizing Nature's Rights: Legal Innovations for Inclusive and Just Conservation

Strengthening legal frameworks is essential to halt environmental degradation and ensure just and inclusive conservation. One pathway is through *human rights-based approaches*, which have gained increasing recognition as vital to biodiversity governance. These include the right to a clean, healthy, and sustainable environment (UNGA, 2022), as well as the rights of Indigenous Peoples, local communities, women, and children (IPBES, 2024). Embedding human rights into environmental policy can reduce environmental injustices, empower vulnerable groups, clarify the accountability of public and private actors, and enhance compliance with law, thereby improving both effectiveness and legitimacy of conservation measures.

In parallel, the emerging paradigm of the *rights of nature* challenges Western legal traditions that prioritize individual over collective well-being. Recognized in some national constitutions and local ordinances, rights of nature frameworks grant legal standing to ecosystems and species, creating a normative shift toward relational and ecological values in law (IPBES, 2024). While their implementation remains contested and context-dependent, such frameworks open new possibilities for safeguarding biodiversity and regenerating ecosystems, as illustrated by the legal personhood of the Whanganui River in Aotearoa New Zealand (see Box 15).

Another proposed innovation is the *recognition of ecocide* as an international crime, defined as severe, widespread, or long-term environmental harm caused by unlawful or wanton acts (Higgins et al., 2013). Establishing ecocide in international law could provide a powerful accountability mechanism, compelling governments and corporations to prevent large-scale ecological damage and creating stronger incentives for conservation.

Together, these legal innovations, including human rights-based approaches, rights of nature, and the recognition of ecocide, offer complementary pathways for embedding justice, accountability, and ecological integrity into biodiversity governance, thereby advancing transformative change.

Box 15: The Whanganui River (Aotearoa New Zealand)

In 2017, the Whanganui River in New Zealand was the first river in the world to be granted legal personhood through the Te Awa Tupua Act. Through the Act, the river is being recognized as "an indivisible and living whole" with rights and responsibilities. Rooted in the Māori worldview *"Ko au te awa, ko te awa ko au"* ("I am the River and the River is me"), the Act emerged from Treaty of Waitangi negotiations to address historic grievances. The River is represented by two guardians, one from the Whanganui iwi and one from the Crown, who jointly advocate for its wellbeing. This case demonstrates how recognizing the rights of nature can embed Indigenous values in governance and create innovative legal mechanisms for inclusive and just conservation (Bosselmann and Williams, 2025).

5 Synthesis and Outlook

The triple planetary crisis has emerged as a single, interconnected system of risks, driven by fossil fuel dependence, unsustainable resource use, and entrenched inequalities. These drivers reinforce each other, destabilizing ecosystems, eroding resilience, and deepening social vulnerabilities. Addressing them requires responses that match this complexity: systemic, cross-sectoral, and justice-oriented. This report has examined three interdependent pathways toward such systemic solutions: governing resource use, deploying NbS, and advancing systemic transformation.

- **Resource use and societal metabolism:** Resource extraction and processing drive more than half of global greenhouse gas emissions and over 90% of biodiversity loss and water stress. Material use has tripled in the last 50 years and continues to rise. Governing societal metabolism is therefore essential. While circular economy and efficiency measures reduce pressures, research makes clear that real transformation depends on reorganizing how societies meet human needs. This requires systemic shifts in provisioning systems such as energy, food, housing, and mobility; stronger governance and equity frameworks; science-based targets; and international cooperation. Crucially, efficiency must be paired with sufficiency and justice. Sectoral instruments such as the Plastics Treaty illustrate how global governance can address entire life cycles, eliminate pollution, and reinforce synergies with other multilateral agreements to safeguard planetary health.

- **Nature-based solutions:** Healthy ecosystems are indispensable for climate regulation, biodiversity recovery, and pollution reduction. NbS–actions to protect, conserve, restore, and manage ecosystems–can sequester carbon, filter pollutants, buffer communities from hazards, and secure food and water systems while providing social co-benefits. Yet their transformative potential depends on how they are conceived and governed. NbS must move beyond narrow "win–win" framings to embrace uncertainty, integrate diverse knowledge, and ensure democratic participation. When designed inclusively, NbS can redistribute benefits, reduce inequalities, and act as vehicles for systemic sustainability transformations. When treated as technocratic fixes or greenwashing tools, they risk reinforcing the very injustices they seek to overcome.

- **Systemic transformation:** Both resource governance and NbS ultimately depend on systemic transformation. The shared root causes of the triple crisis demand fundamental change in views, structures, and practices. This entails shifting societal values to recognize the multiple ways nature matters; reshaping governance, markets, and financial flows to dismantle harmful incentives and embed justice; and restoring ecosystems through inclusive, regenerative practices. Transformation must center equity and justice, recognizing the Most Affected People and Areas (MAPA) not just as vulnerable populations but as agents of change. Indigenous knowledge, local stewardship, and rights-based approaches are indispensable to building legitimacy and resilience. Far from being abstract, systemic transformation is a practical foundation: without it, resource efficiency and NbS remain fragmented; with it, they can be scaled, integrated, and anchored in justice.

Taken together, these three pathways underscore a common message: incremental, siloed action is no longer enough. Governing resource use, scaling transformative NbS, and advancing systemic change are mutually reinforcing strategies that can break cycles of degradation and inequality. Pursued together, they offer the possibility of turning today's triple planetary crisis into an opportunity for regeneration, justice, and resilience. The outlook is urgent, as planetary boundaries continue to be breached, but also hopeful: integrated solutions exist that can deliver co-benefits across ecological and social systems, laying the foundation for a more just and sustainable future.

Box 16: Key considerations for Policymakers

- **Govern societal metabolism:** Establish ambitious, science-based targets for resource use at global and national levels. Reform provisioning systems in energy, food, housing, and mobility to reduce material throughput, and democratize decision-making to ensure equitable access. Move beyond efficiency alone by embedding sufficiency and justice in resource governance and align sectoral instruments–such as the Plastics Treaty–with wider sustainability goals.

- **Scale transformative NbS:** Mainstream NbS into biodiversity, climate, urban, and landscape planning frameworks as multifunctional solutions. Mobilize predictable, long-term finance and create mechanisms that reflect the public-good nature of NbS. Ensure inclusive governance and co-production of knowledge so that NbS embrace uncertainty, build legitimacy, and deliver durable benefits for ecosystems and communities.

- **Advance systemic transformation:** Reshape governance, markets, and financial flows to dismantle harmful incentives and embed equity and justice. Recognize MAPA and Indigenous Peoples as agents of change, placing their rights and knowledge at the center of policies and their implementation. Strengthen synergies across sectors and scales to avoid trade-offs and build resilience, turning fragmented efforts into coherent strategies for a just and sustainable future.

6 List of references

Assefa-Aragaw, T., Bailly, D., Bartolotta, J., Baztan, J., Bergmann, M., Carney-Almroth, B., Castillo, A., Collins, T., Cordier, M., De-Falco, F., Deeney, M., Farrelly, T., Fernandez, M., Gall, S., Álava, J.-J., Gammage, T., Ghiglione, J.-F., Gündoğdu, S., Hansen, T., … Wagner, M. (2024). *Primary Plastic Polymers: Urgently needed upstream reduction*. https://doi.org/10.5281/ZENODO.10906376

Baztan, J., Jorgensen, B., Carney Almroth, B., Bergmann, M., Farrelly, T., Muncke, J., Syberg, K., Thompson, R., Boucher, J., Olsen, T., Álava, J.-J., Aragaw, T. A., Bailly, D., Jain, A., Bartolotta, J., Castillo, A., Collins, T., Cordier, M., De-Falco, F., … Wagner, M. (2024). Primary plastic polymers: Urgently needed upstream reduction. *Cambridge Prisms: Plastics*, *2*, e7. https://doi.org/10.1017/plc.2024.8

Biswal, B. K., Bolan, N., Zhu, Y.-G., and Balasubramanian, R. (2022). Nature-based Systems (NbS) for mitigation of stormwater and air pollution in urban areas: A review. *Resources, Conservation and Recycling*, *186*, 106578. https://doi.org/10.1016/j.resconrec.2022.106578

Bosselmann, K., and Williams, T. (2025, January 29). *The River as a Legal Person: The case of the Whanganui River in New Zealand*. Heinrich Böll Stiftung. https://www.boell.de/en/2025/01/29/river-legal-person-case-whanganui-river-new-zealand

Bringezu, S., Potočnik, J., Schandl, H., Lu, Y., Ramaswami, A., Swilling, M., and Suh, S. (2016). Multi-Scale Governance of Sustainable Natural Resource Use–Challenges and Opportunities for Monitoring and Institutional Development at the National and Global Level. *Sustainability*, *8*(8), 778. https://doi.org/10.3390/su8080778

Burgos, N., Rizzi, D., and Davis, M. (2024). *Bridging Continents. Exploring the state-play of Nature-based Solutions in the EU and LAC: Building a foundation for collaboration.* European Commission, Directorate-General for Research and Innovation, Publicatios Office of the European Union. https://www.ecologic.eu/sites/default/files/publication/2024/50173-bridging-continents.pdf

Calisto Friant, M., Vermeulen, W. J. V., and Salomone, R. (2024). Transition to a Sustainable Circular Society: More than Just Resource Efficiency. *Circular Economy and Sustainability*, *4*(1), 23–42. https://doi.org/10.1007/s43615-023-00272-3

Cantzler, J., Creutzig, F., Ayargarnchanakul, E., Javaid, A., Wong, L., and Haas, W. (2020). Saving resources and the climate? A systematic review of the circular economy and its mitigation potential. *Environmental Research Letters*, *15*(12), 123001. https://doi.org/10.1088/1748-9326/abbeb7

CBD. (2025, August 18). *Joint Liaison Group of the Rio Conventions Joint Liaison Group*. Convention on Biological Diversity. https://www.cbd.int/rio

CFFA. (2025, June 9). *Galapagos debt-swap: "These deals are being used to privatize the management of strategic areas without the consent of those who inhabit these territories."* Coalition for Fair Fisheries Arrangements. https://www.cffacape.org/publications-blog/galapagos-debt-swap-these-deals-are-being-used-to-privatize-the-management-of-strategic-areas-without-the-consent-of-those-who-inhabit-these-territories

CFS. (2014). *Report of the 41st Session of the Committee on World Food Security (Rome, 13-18 October 2014)*. Committee on World Food Security. https://openknowledge.fao.org/handle/20.500.14283/mm369e

Chakori, S., Aziz, A. A., Smith, C., and Dargusch, P. (2021). Untangling the underlying drivers of the use of single-use food packaging. *Ecological Economics*, *185*, 107063. https://doi.org/10.1016/j.ecolecon.2021.107063

Chaplowe. (2025). *The approach to transformational change in multilateral climate funds: AF, CIF, GEF and GCF, Synthesis Report*. https://www.adaptation-fund.org/wp-content/uploads/2025/06/MCFs-Transformational-Change_220525_3.pdf

Circle Economy, and Deloitte. (2023). *The Circularity Gap Report 2023*. Circular Economy. https://www.circularity-gap.world/2023#download

Circle Economy, and Deloitte. (2025). *Circularity Gap Report 2025*. Circle Economy. https://www.circularity-gap.world/2025

CJRF. (2021). *SmartICE. Bridging New Technologies with Traditional Knowledge.* Climate Justice Resilience Fund. https://www.cjrfund.org/smartice

Clube, R. K. M., and Tennant, M. (2023). What would a human-centred 'social' Circular Economy look like? Drawing from Max-Neef's Human-Scale Development proposal. *Journal of Cleaner Production*, *383*, 135455. https://doi.org/10.1016/j.jclepro.2022.135455

Cohen-Shacham, E., Walters, G., Janzen, C., and Maginnis, S. (Eds.). (2016). *Nature-based solutions to address global societal challenges*. IUCN International Union for Conservation of Nature. https://doi.org/10.2305/IUCN.CH.2016.13.en

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

Davis, M., Burgos, De Vreese, R., Maestre-Andres, S., Xidous, D., and Zingraff-Hamed, A. (2025). *Co-creating nature-based solutions with commonly excluded stakeholders: Insights from practice and research. NetworkNature+ Task Force 6.*

D'Souza, V. A. (2025). *Indigenous approaches to "Nature". Insights at a Time of Planetary Crisis*. Laudato Si' Research Institute (LSRI). https://lsri.campion.ox.ac.uk/researchpaper05

Dunlop, T., Khojasteh, D., Cohen-Shacham, E., Glamore, W., Haghani, M., Van Den Bosch, M., Rizzi, D., Greve, P., and Felder, S. (2024). The evolution and future of research on Nature-based Solutions to address societal challenges. *Communications Earth & Environment*, *5*(1), 132. https://doi.org/10.1038/s43247-024-01308-8

Durand, C., Hofferberth, E., and Schmelzer, M. (2024). Planning beyond growth: The case for economic democracy within ecological limits. *Journal of Cleaner Production*, *437*, 140351. https://doi.org/10.1016/j.jclepro.2023.140351

Ellen MacArthur Foundation. (2024). *Building Prosperity: Unlocking the potential of a nature-positive, circular economy for Europe*. Ellen MacArthur Foundation. https://www.ellenmacarthurfoundation.org/building-prosperity

European Commission. (2012). *Ecodesign Yor Future. How Ecodesign can help the environment by making products smarter.* https://build-up.ec.europa.eu/sites/default/files/content/Brochure-Ecodesign-Your-Future-15022012.pdf

Fanning, A. L., O'Neill, D. W., Hickel, J., and Roux, N. (2022). The social shortfall and ecological overshoot of nations. *Nature Sustainability*, *5*(1), Article 1. https://doi.org/10.1038/s41893-021-00799-z

FAO. (2025). *Waste to Resource: Circular Economy can increase resilience*. Food and Agriculture Organisation of the United Nations. https://www.fao.org/land-water/overview/onehealth/circular/en/

GACERE. (2024). *Circular Economy, Pollution and Chemicals–Working Paper*. Global Alliance on Circular Eonomy and Ressource Efficiency (GACERE). https://www.unido.org/sites/default/files/unido-publications/2024-07/GACERE-Working-paper-Circular-Economy-Pollution.pdf

GEF. (2025). *Progress Report On The Long-Term Vision On Complementarity, Coherence And Collaboration Between The Green Climate Fund And The Global Environment Facility 2025*. Green Climate Fund. https://www.thegef.org/sites/default/files/documents/2025-

05/EN_GEF.C.69.Inf_.09_Progress%20Report%20on%20the%20Long-Term%20Vision%20on%20Complementarity%2C%20Coherence%20and%20Collaboration%20between%20GCF%20and%20GEF%202025.pdf

Genovese, A., and Pansera, M. (2021). The Circular Economy at a Crossroads: Technocratic Eco-Modernism or Convivial Technology for Social Revolution? *Capitalism Nature Socialism*, *32*(2), 95–113. https://doi.org/10.1080/10455752.2020.1763414

Georgescu-Roegen, N. (1971). *The Entropy Law and the Economic Process*. Harvard University Press. https://content.csbs.utah.edu/~lozada/Adv_Resource_Econ/En_Law_Econ_Proc_Cropped_Optimized_Clearscan.pdf

GIZ. (2020). *Agroecology–Factsheet*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. https://www.giz.de/en/downloads/giz2020_en_Agroecology_SV%20Nachhaltige%20Landwirtschaft_05-2020.pdf

Guerrero-Villegas, W., Rosero-Rosero, M., Layana-Bajana, E.-M., and Villares-Villafuerte, H. (2025). Circular Agriculture Models: A Systematic Review of Academic Contributions. *Sustainability*, *17*(15), 7146. https://doi.org/10.3390/su17157146

Haberl, H., Wiedenhofer, D., Pauliuk, S., Krausmann, F., Müller, D. B., and Fischer-Kowalski, M. (2019). Contributions of sociometabolic research to sustainability science. *Nature Sustainability*, *2*(3), 173–184. https://doi.org/10.1038/s41893-019-0225-2

Haberl, H., Wiedenhofer, D., Virág, D., Kalt, G., Plank, B., Brockway, P., Fishman, T., Hausknost, D., Krausmann, F., Leon-Gruchalski, B., Mayer, A., Pichler, M., Schaffartzik, A., Sousa, T., Streeck, J., and Creutzig, F. (2020). A systematic review of the evidence on decoupling of GDP, resource use and GHG emissions, part II: Synthesizing the insights. *Environmental Research Letters*, *15*(6), 065003. https://doi.org/10.1088/1748-9326/ab842a

Hafferty, C., Tomude, E. S., Wagner, A., McDermott, C., and Hirons, M. (2025). Unpacking the politics of Nature-based Solutions governance: Making space for transformative change. *Environmental Science & Policy*, *163*, 103979. https://doi.org/10.1016/j.envsci.2024.103979

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

Hertwich, E., Lifset, R., Pauliuk, S., Heeren, N., Ali, S., Tu, Q., Ardente, F., Berrill, P., Fishman, T., Kanaoka, K., Kulczycka, J., Makov, T., Masanet, E., and Wolfram, P. (2020). *Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low-Carbon Future*. Zenodo. https://doi.org/10.5281/ZENODO.3542680

Hickel, J., Dorninger, C., Wieland, H., and Suwandi, I. (2022). Imperialist appropriation in the world economy: Drain from the global South through unequal exchange, 1990–2015. *Global Environmental Change*, *73*, 102467. https://doi.org/10.1016/j.gloenvcha.2022.102467

Higgins, P., Short, D., and South, N. (2013). Protecting the planet: A proposal for a law of ecocide. *Crime, Law and Social Change*, *59*(3), 251–266. https://doi.org/10.1007/s10611-013-9413-6

Hiraishi, K. (2023, November 28). *"We're on the right track": Hā'ena's community subsistence fishing area sees positive results*. Hawai'i Public Radio. https://www.hawaiipublicradio.org/local-news/2023-11-28/haenas-community-subsistence-fishing-area-sees-positive-results

IPBES (Ed.). (2019a). *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. (2019b). *Global Assessment Report on Biodiversity and Ecosystem Services*. http://www.ipbes.net/global-assessment

IPBES. (2024). *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*. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. https://www.ipbes.net/transformative-change-assessment

IPCC. (2019). Risk Management and Decision Making in Relation to Sustainable Development. In *Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*. Cambridge University Press. https://doi.org/10.1017/9781009157988.009

IPCC. (2022). *Summary for Policymakers. Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*.

IPCC. (2023). *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

IRP. (2023). *Enabling the energy transition: Mitigating growth in material and energy needs, and building a sustainable mining sector.* International Resource Panel. https://www.resourcepanel.org/reports/enabling-energy-transition

IRP. (2025a). *Call to Action for 21st Century Global Materials Stewardship – Annex (v1.0)*. https://globalmaterials.earth/wp-content/uploads/2025/05/ANNEX-v1.0-CTA.pdf

IRP. (2025b). *Tackling Governance and Financing for Sustainability Transitions*. https://www.resourcepanel.org/reports/tackling-governance-and-financing-sustainability-transitions

IUCN. (2020). *IUCN Global Standard for Nature-based Solutions. A user-friendly framework for the verification, design and scaling up of NbS.* International Union for Conservation of Nature (IUCN). https://portals.iucn.org/library/sites/library/files/documents/2020-020-En.pdf

Iwaszuk, E., Rudik, G., Duin, L., Mederake, L., Davis, M., and Naumann, S. (2019). *Addressing Climate Change in Cities–Catalogue of Uban Nature-Based Solutions*. Ecologic Institute, The Sendzimir Foundation. https://www.ecologic.eu/sites/default/files/publication/2020/addressing-climate-change-in-cities-nbs_catalogue.pdf

Jansen, L. J. M., and Kalas, P. P. (2020). Improving Governance of Tenure in Policy and Practice: A Conceptual Basis to Analyze Multi-Stakeholder Partnerships for Multi-Stakeholder Transformative Governance Illustrated with an Example from South Africa. *Sustainability*, *12*(23), 9901. https://doi.org/10.3390/su12239901

Johnson, B. A., Kumar, P., Okano, N., Dasgupta, R., and Shivakoti, B. R. (2022). Nature-based solutions for climate change adaptation: A systematic review of systematic reviews. *Nature-Based Solutions*, *2*, 100042. https://doi.org/10.1016/j.nbsj.2022.100042

Kabisch, N., Frantzeskaki, N., Pauleit, S., Naumann, S., Davis, M., Artmann, M., Haase, D., Knapp, S., Korn, H., Stadler, J., Zaunberger, K., and Bonn, A. (2016). Nature-based solutions to climate change mitigation and adaptation in urban areas: Perspectives on indicators, knowledge gaps, barriers, and opportunities for action. *Ecology and Society*, *21*(2), art39. https://doi.org/10.5751/ES-08373-210239

Kabisch, N., Korn, H., Stadler, J., and Bonn, A. (Eds.). (2017). *Nature-Based Solutions to Climate Change Adaptation in Urban Areas: Linkages between Science, Policy and Practice*. Springer International Publishing. https://doi.org/10.1007/978-3-319-56091-5

Kato-Huerta, J., and Geneletti, D. (2022). Environmental justice implications of nature-based solutions in urban areas: A systematic review of approaches, indicators, and outcomes. *Environmental Science & Policy*, *138*, 122–133. https://doi.org/10.1016/j.envsci.2022.07.034

Knoblauch, D., Felthöfer, C., Heni, Y., Burgos Cuevas, N., and Best, A. (2025). *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-8107

Korhonen-Kurki, K., D'Amato, D., Belinskij, A., Lazarevic, D., Leskinen, P., Nylén, E.-J., Pappila, M., Penttilä, O., Pitzén, S., Pykäläinen, N., Turunen, T., and Vikström, S. (2025). Transformative governance: Exploring theory of change and the role of the law. *Earth System Governance*, *23*, 100230. https://doi.org/10.1016/j.esg.2024.100230

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

Kreinin, H., Fuchs, D., Mamut, P., Hirth, S., and Lange, S. (2024). Transforming provisioning systems to enable 1.5° lifestyles in Europe? Expert and stakeholder views on overcoming structural barriers. *Sustainability: Science, Practice and Policy*, *20*(1), 2372120. https://doi.org/10.1080/15487733.2024.2372120

Kupilas, B., Cuevas, N. B., Davis, M., Elkina, E., and McDonald, H. (2025). *Mapping policy and co-operate initiative landscapes for systemic change towards a nature-positive economy (Deliverable 1.3).* https://doi.org/10.5281/ZENODO.15309698

Lengieza, M. L., and Aviste, R. (2025). Relationships between people and nature: Nature connectedness and relational environmental values. *Current Opinion in Psychology*, *62*, 101984. https://doi.org/10.1016/j.copsyc.2024.101984

Mayer, P. M., Moran, K. D., Miller, E. L., Brander, S. M., Harper, S., Garcia-Jaramillo, M., Carrasco-Navarro, V., Ho, K. T., Burgess, R. M., Thornton Hampton, L. M., Granek, E. F., McCauley, M., McIntyre, J. K., Kolodziej, E. P., Hu, X., Williams, A. J., Beckingham, B. A., Jackson, M. E., Sanders-Smith, R. D., … Mendez, M. (2024). Where the rubber meets the road: Emerging environmental impacts of tire wear particles and their chemical cocktails. *Science of The Total Environment*, *927*, 171153. https://doi.org/10.1016/j.scitotenv.2024.171153

McCormick, K., Kiss, B., Bulkeley, H., Davis, M., Raven, R., Luque-Ayala, A., and Hörschelmann, K. (2024). *Urban Nature New Directions for City Futures* (Cambridge University Press).

Millward-Hopkins, J., Fisch-Romito, V., Nick, S., and Chevrel, E. (2025). Energy requirements for securing wellbeing in Switzerland and the space for affluence and inequality. *Nature Communications*, *16*(1), 4066. https://doi.org/10.1038/s41467-025-59276-2

Olsen, T., Gonella, S., Palm, E., Jorgensen, B., Carney Almroth, B., Syberg, K., Tangri, N., Castillo Castillo, A., and Fieber, R. (2025). *Article 6 on Supply / Sustainable Production: Pathways for Achieving a Global PPP Target and an Effective Treaty*. https://doi.org/10.5281/ZENODO.15639284

Olusola, A., and Oyewole, S. (2025). The Role of Circular Economy in Achieving Sustainability: A Case Study of Songhai Integrated Farming Initiatives. *International Journal of Humanities Social Science and Management*, *5*(2), 931–941.

Otto, I. M., Kim, K. M., Dubrovsky, N., and Lucht, W. (2019). Shift the focus from the super-poor to the super-rich. *Nature Climate Change*, *9*(2), 82–84. https://doi.org/10.1038/s41558-019-0402-3

Pan, H., Page, J., Shi, R., Cong, C., Cai, Z., Barthel, S., Thollander, P., Colding, J., and Kalantari, Z. (2023). Contribution of prioritized urban nature-based solutions allocation to carbon neutrality. *Nature Climate Change*, *13*(8), 862–870. https://doi.org/10.1038/s41558-023-01737-x

Parrique, T., Barth, J., Briens, F., Kerschner, C., Kraus-Polk, A., Kuokkanen, A., and Spangenberg, J. H. (2019). *Decoupling Debunked: Evidence and Arguments Against Green Growth as a Sole Strategy for Sustainability*. European Environmental Bureau. https://eeb.org/library/decoupling-debunked/

Pew. (2023, September 14). *To Protect Galápagos Islands, Ecuador Turns to Innovative Financing. Debt conversion will fund perpetual conservation of renowned marine habitat*. https://www.pew.org/en/research-and-analysis/fact-sheets/2023/05/to-protect-galapagos-islands-ecuador-turns-to-innovative-financing

Pew Bertarelli Ocean Legacy. (2025). *Innovative Financing Tool Helps Protect Galapagos Islands.* https://www.pew-bertarelli-ocean-legacy.org/-/media/assets/extranets/pbol/galapagos_brief_v7.pdf

Pineault, É. (2025). *Die soziale Ökologie des Kapitals* (C. Frings, Trans.; 1. Auflage). Dietz.

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

Pörtner, H.-O., Scholes, R. J., Arneth, A., Barnes, D. K. A., Burrows, M. T., Diamond, S. E., Duarte, C. M., Kiessling, W., Leadley, P., Managi, S., McElwee, P., Midgley, G., Ngo, H. T., Obura, D., Pascual, U., Sankaran, M., Shin, Y. J., and Val, A. L. (2023). Overcoming the coupled climate and biodiversity crises and their societal impacts. *Science*, *380*(6642), eabl4881. https://doi.org/10.1126/science.abl4881

Potting, J., Hekkert, M., Worrell, E., and Hanemaaijer, A. (2017). *Circular Economy: Measuring Innovation in the Product Chain* (No. 2544 (Planbureau voor de Leefomgeving)).

ReBuilt. (2024, October 15). *Good Practice Examples of EU Projects on Re-use of Construction Waste in Central Europe*. Interreg Central Europe. https://www.interreg-central.eu/news/good-practice-examples-of-eu-projects-on-re-use-of-construction-waste-in-central-europe/

Richardson, K., Steffen, W., Lucht, W., Bendtsen, J., Cornell, S. E., Donges, J. F., Drüke, M., Fetzer, I., Bala, G., Von Bloh, W., Feulner, G., Fiedler, S., Gerten, D., Gleeson, T., Hofmann, M., Huiskamp, W., Kummu, M., Mohan, C., Nogués-Bravo, D., … Rockström, J. (2023). Earth beyond six of nine planetary boundaries. *Science Advances*, *9*(37), 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

Rodgers, K., Graham, A., Han, J., Stefanak, M., Stender, Y., Tsang, A., Weible, and Stamoulis, K. (2021). *2016-2020 Five Year Efficacy Study of the Managment Regulations within the Community Based Subsistence Fishing Area of Hāʻena Kauaʻi*. Coral Reef Assessment and Monitoring Program. https://dlnr.hawaii.gov/holomua/files/2023/01/2020-Haena-Report-Final.pdf

Rödl, M. B., Åhlvik, T., Bergeå, H., Hallgren, L., and Böhm, S. (2022). Performing the Circular economy: How an ambiguous discourse is managed and maintained through meetings. *Journal of Cleaner Production*, *360*, 132144. https://doi.org/10.1016/j.jclepro.2022.132144

Schaffartzik, A., Pichler, M., Pineault, E., Wiedenhofer, D., Gross, R., and Haberl, H. (2021). The transformation of provisioning systems from an integrated perspective of social metabolism and political economy: A conceptual framework. *Sustainability Science*, *16*(5), 1405–1421. https://doi.org/10.1007/s11625-021-00952-9

Schönbauer, S., and Müller, R. (2021). A Risky Object? How Microplastics Are Represented in the German Media. *Science Communication*, *43*(5), 543–569. https://doi.org/10.1177/10755470211030519

Scientists' Coalition for an Effective Plastic Treaty. (2023). *Fact Sheet: Plastic pollution at each life stage*. https://ikhapp.org/material/fact-sheet-plastic-pollution-at-each-life-stage/

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

Seddon, N., Smith, A., Smith, P., Key, I., Chausson, A., Girardin, C., House, J., Srivastava, S., and Turner, B. (2021). Getting the message right on nature-based solutions to climate change. *Global Change Biology*, *27*(8), 1518–1546. https://doi.org/10.1111/gcb.15513

Seymour, F., and Langer, P. (2021). Consideration of Nature-Based Solutions as Offsets in Corporate Climate Change Mitigation Strategies. *World Resources Institute*. https://doi.org/10.46830/wriwp.20.00043

Sharma. (2025). *Zero-Waste Farming Villages: How Circular Economy Principles Are Reinventing Rural Agriculture*. Earth5R. https://earth5r.org/zero-waste-farming-villages-circular-economy-india/#:~:text=Reports%20from%20the%20Ministry%20of%20Agriculture%20show%20stagnating,advocating%20circularity%20as%20a%20cornerstone%20of%20rural%20revitalization.

Sharma, I., and Birman, S. (2024). Biodiversity Loss, Ecosystem Services, and Their Role in Promoting Sustainable Health. In P. Singh and N. Yadav (Eds.), *The Climate-Health-Sustainability Nexus* (pp. 163–188). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-56564-9_7

Simelton, E., Carew-Reid, J., Coulier, M., Damen, B., Howell, J., Pottinger-Glass, C., Tran, H. V., and Van Der Meiren, M. (2021). NBS Framework for Agricultural Landscapes. *Frontiers in Environmental Science*, *9*, 678367. https://doi.org/10.3389/fenvs.2021.678367

SmartICE. (2022). *SmartICE community ice monitoring. Can technology, combined with Inuit knowledge, help make sea ice travel safer?* Polar Polaire. https://www.canada.ca/en/polar-knowledge/publications/aqhaliat/volume-4/infosheets.html#smartice

Steinberger, J., Guerin, G., Hofferberth, E., and Pirgmaier, E. (2024). Democratizing provisioning systems: A prerequisite for living well within limits. *Sustainability: Science, Practice and Policy*, *20*(1), 2401186. https://doi.org/10.1080/15487733.2024.2401186

Tölg, R., and Fuentes, C. (2025). Care and circularity: How the enactment of care enables and shapes the circular consumption of clothing. *Consumption and Society*, *4*(2), 213–231. https://doi.org/10.1332/27528499Y2024D000000032

UN. (2024). *Synergy Solutions for Climate and SDG Action: Bridging the Ambition Gap for the Future We Want.* United Nations Department of Economic and Social Affairs.

UNCCD. (2023). *Synergy Brief. Land Restoration to Safeguard Nature and Livelihoods.* United Nations Convention to Combat Desertification.

UNDCC. (2024). *Harmony in action for land restoration: Linking social protection, financial inclusion and disaster risk finance. A guide for UNCCD Parties.* United Nations Convention to Combat Desertification ; UNU EHS.

UNDP. (2024, July 31). *Indigenous knowledge is crucial in the fight against climate change – here's why*. Climate Promise UNDP. https://climatepromise.undp.org/news-and-stories/indigenous-knowledge-crucial-fight-against-climate-change-heres-why

UNEA. (2022). *Res. 5 Nature-based solutions for supporting sustainable development* [Resolution UNEP/EA.5/Res.5]. United Nations Environment Assembly. https://wedocs.unep.org/bitstream/handle/20.500.11822/39864/NATURE-BASED%20SOLUTIONS%20FOR%20SUPPORTING%20SUSTAINABLE%20DEVELOPMENT.%20English.pdf?sequence=1&isAllowed=y

UNEP. (2024). *Global Resources Outlook 2024*. https://www.resourcepanel.org/reports/global-resources-outlook-2024

UNEP, and IUCN. (2021). *Nature-based solutions for climate change mitigation*. United Nations Environment Programme (UNEP), International Union for Conservation Nature (IUCN). https://www.unep.org/resources/report/nature-based-solutions-climate-change-mitigation

UNEP-ISC. (2024). *Navigating New Horizons: A global foresight report on planetary health and human wellbeing*. https://wedocs.unep.org/20.500.11822/45890

UNEP-WCMC. (2023, August). *Championing Indigenous People's Stewardship of Biodiversity.* https://www.unep-wcmc.org/en/news/championing-indigenous-peoples-stewardship-of-biodiversity

UNGA. (2022). *A/RES/76/300. The human right to a clean, healthy and sustainable environment.* https://digitallibrary.un.org/record/3983329?v=pdf

Urban Nature Atlas. (2024, June). *Community Mangrove Biodiversity Conservation in Penang*. https://una.city/nbs/penang/community-mangrove-biodiversity-conservation-penang

Urban Nature Atlas. (2025, April). *The Boston Project: Sustainable Neighborhood*. https://una.city/nbs/cartagena-fua/boston-project-sustainable-neighborhood

Vélez-Henao, J. A., and Pauliuk, S. (2023). Material Requirements of Decent Living Standards. *Environmental Science & Technology*, *57*(38), 14206–14217. https://doi.org/10.1021/acs.est.3c03957

Wheeler, H. C., and Root-Bernstein, M. (2020). Informing decision-making with Indigenous and local knowledge and science. *Journal of Applied Ecology*, *57*(9), 1634–1643. https://doi.org/10.1111/1365-2664.13734

WWF. (2020). *Bending the curve: The restorative power of planet-based diets.* World Wildlife Fund (WWF).

Xie, L., and Bulkeley, H. (2020). Nature-based solutions for urban biodiversity governance. *Environmental Science & Policy*, *110*, 77–87. https://doi.org/10.1016/j.envsci.2020.04.002