Reviews and syntheses: Current perspectives on biosphere research - 2024: 8 findings from ecology, sociology and economics

Friedrich J. Bohn[1,2], Ana Bastos[3], Romina Martin[4], Anja Rammig[5], Niak Sian Koh[6], Giles B. Sioen[7,8], Bram Buscher[9], Louise Carver[10], Fabrice DeClerck[11], Moritz Drupp[12,13,14,15], Robert Fletcher[9], Matthew Forrest[16], Alexandros Gasparatos[17], Alex Godoy-Faúndez[18], Gregor Hagedorn[19], Martin C. Hänsel[20], Jessica Hetzer[16], Thomas Hickler[16,21], Cornelia B. Krug[22], Stasja Koot[9,23], Xiuzhen Li[24], Amy Luers[25], Shelby Matevich[9], H. Damon Matthews[26], Ina C. Meier[12], Mirco Migliavacca[27], Awaz Mohamed[12], Sungmin O[28], David Obura[29], Ben Orlove[30], Rene Orth[31], Laura Pereira[32], Markus Reichstein[33], Lerato Thakholi[9], Peter Verburg[34], and Yuki Yoshida[35]

[1]Helmholtz Centre for Environmental Research GmbH - UFZ, Leipzig, Germany
[2]BAM! Bock auf Morgen - Nachhaltigkeit Beratung Medien GmbH VE, Berlin, Germany
[3]Institute for Earth System Science and Remote Sensing, Leipzig University, Leipzig, Germany
[4]Stockholm Resilience Centre, Stockholm University, Stockholm, Sweden
[5]TUM School of Life Sciences Weihenstephan, Technische Universität München, Freising, Germany
[6]University of Oxford, Oxford, UK
[7]Future Earth Global Secretariat, Tsukuba, Japan
[8]Sustainable Society Design Center, Graduate School of Frontier Sciences, The University of Tokyo, Kashiwa-no-ha, Japan
[9]Wageningen University, Wageningen, The Netherlands
[10]Lancaster University, Lancaster, UK
[11]Alliance of Bioversity & CIAT, Montpellier, France
[12]University of Hamburg, Hamburg, Germany
[13]University of Gothenburg, Göteborg, Sweden
[14]CESifo, München, Germany
[15]Center for Earth System Research and Sustainability, Hamburg, Germany
[16]Senckenberg Biodiversity and Climate Research Center (SBiK-F), Frankfurt, Germany
[17]University of Tokyo, Japan
[18]Sustainability Research Center, Facultad de Ingenieria, Universidad del Desarrollo, Santiago, Chile
[19]Museum für Naturkunde - Leibniz-Institut für Evolutions- und Biodiversitätsforschung (MfN), Berlin, Germany
[20]Institute for Infrastructure and Resource Management, Leipzig University, Leipzig, Germany
[21]Goethe University Frankfurt, Frankfurt, Germany
[22]University of Zurich, Zürich, Switzerland
[23]University of Johannesburg, Johannesburg, South Africa
[24]East China Normal University, Shanghai, China
[25]Microsoft, Redmond, Washington, USA
[26]Concordia University, Montreal, Canada
[27]European Commission, Joint Research Centre, Ispra (VA), Italy
[28]Department of AI Software, Kangwon National University, Samcheock, South Korea
[29]CORDIO East Africa, Mombasa, Kenya
[30]Columbia University, New York City, USA
[31]University of Freiburg, Freiburg, Germany
[32]University of the Witwatersrand, Johannesburg, South Africa
[33]Max-Planck-Institute for Biogeochemistry, Jena, Germany
[34]Vrije Universiteit Amsterdam, Amsterdam, the Netherlands

[35]Center for Climate Change Adaptation, National Institute for Environmental Studies, Ibaraki, Japan
Correspondence: friedrich.bohn@ufz.de (friedrich.bohn@ufz.de)

Abstract. This review of recent advances in biosphere research aims to provide information on selected issues related to changes in biodiversity, ecosystem functioning, social and economic interactions with ecosystems, and the impacts of climate change on the biosphere. An interdisciplinary panel of experts selected eight topics from a public survey based on relevance and scientific evidence that have the potential to guide future actions as well as inspire future research questions. Our focus is on the interactions between climate, biosphere and society, and on strategies to sustain, restore or promote ecosystems and their services. The themes focus on innovative opportunities for coastal habitats, forests linkages to droughts, and increase of fire risks. We further discuss nature-based CDR implementation risks, and the share of (semi-) natural habitats in the landscape. Finally we highlight the improtance of comprehensive international policy packages, the social-economic value of ecosystems in the future and present the idea of convivial conservation. Analysing the offered solutions of the eight topcis we synthesis four central insights: (i) Improve mechanisms of inclusive decision making, (ii) establish and strengthen incentives for sustainable practices, (iii) measure and share regional features and finally (iv) adopt long lasting holistic landscape management strategies. This review emphasises that the interlinked challenges for ecosystems, including the socio-economic dimensions, require interdisciplinary and integrative approaches to develop effective and sustainable solutions.

1 Introduction

The dynamics and diversity of life on Earth as we know it and its role in the Earth system are increasingly under threat as human activities have changed and continue to change the planet in unprecedented ways. (Watson et al., 2019; Ripple et al., 2023; Rockström et al., 2023; Crutzen, 2006; Stubbins et al., 2021; Cowie et al., 2022; Friedlingstein et al., 2023). As we are entering uncharted territories, it is critical that we use scientific evidence as a foundation for decision-making, taking into account the interrelationships within the complex Earth system. The science has been clear for years on the need to significantly cut greenhouse gas emissions, halt biodiversity loss, reduce chemical pollution, and manage ecosystems sustainably to ensure a livable planet (Hill, 2020; Jaureguiberry et al., 2022; Meinshausen et al., 2022). The intertwined crises of climate change, pollution, and biodiversity loss have their nexus in the biosphere, as all these crises impact natural processes that support life quality, livelihoods, and economies, and thus creating a comprehensive Earth system crisis that threatens human well-being (Pörtner et al., 2021b, 2023).

There is growing recognition from governments and business actors that our economies need to take full account of the impacts on nature and rebalance our demands of resources (Dasgupta and Treasury, 2022; TNDF, 2023). A whole-of-society perspective is needed, as scholars also highlight that fair and just transformations are crucial to reach the global sustainability goals for climate and biodiversity in the areas of food supply, energy and material systems and thus ensuring human well-being in the long term. (Griggs et al., 2013; Leach et al., 2018; Martin et al., 2020; Folke et al., 2021; Pickering et al., 2022; Obura et al., 2023; McDermott et al., 2023; Schlesier et al., 2024). This first report and future reports in this series are intended to support decision-making processes in the coming years by summarizing selected recent findings from biosphere research, thus supplementing existing reports and bridging the gap until the next comprehensive assessment reports are published.

The Intergovernmental Panel on Climate Change (IPCC) and the Intergovernmental Science and Policy Platform on Biodiversity and Ecosystem Services (IPBES) were established to summarize the state of the science on climate change, biodiversity and ecosystem services for policy-makers and thus provide a basis for science-based decision-making. Their reports comprehensively inform stakeholders and decision-makers about the scientific understanding of climate change and biodiversity loss, its impacts, risks and solutions, and the progress of climate action under international pledges and agreements (e.g., IPBES, 2019; IPCC, 2021, 2022a, 2023). However, given the thematic breadth and procedural requirements, IPCC and IPBES assessments take several years to complete. For example, more than eight years elapsed between the publication of the IPCC Assessment Report (AR5) and AR6 Synthesis Report (Pachauri et al., 2014; Lee et al., 2023). The first global IPBES assessment report was published in 2019 (IPBES, 2019), and the second global assessment report is scheduled to be completed in 2028. In addition, major reports provide scientific insights with a considerable time lag. For example, the AR6 Synthesis Report was published in 2023. Still, the cut-off date for the scientific literature reviewed by the three working groups was more than two years earlier . Hence negotiators and decision-makers profit from additional authoritative syntheses and summaries of recent scientific advances relevant to decision-making in the multi-year intervals between these major global reports.

The IPCC and IPBES regularly publish reports on specific aspects of climate change, biodiversity and nature (known as Special Reports). Such reports summarize scientific knowledge related to that aspect from several disciplines, but these reports are not updated after some years and hence get outdated over time. In addition to these special reports, many scientists have published summaries on a wide range of topics under the heading "Scientists' Warning".(e.g. Cavicchioli et al., 2019; Pyšek et al., 2020; Ripple et al., 2020). Additionally, there are regular reports like the State of the Global Climate and the Global Carbon Budget (e.g., Pörtner et al., 2019; 2024, 2024; Le Quéré et al., 2013; Friedlingstein et al., 2023) and more recently the State of Wildfires (Jones et al., 2024). Further, FAO publications such as the State of the World's Forests and the State of Agricultural Commodity Markets report on biodiversity loss and ecosystem services (e.g., IPBES, 2023; FAO, 2022a, b). In addition to these reports at international level, there is also a plethora of regular national reports on various aspects of the crisis in the Earth system. These well-recognized reports update diagnostic indicators and measures familiar to those involved in or following corresponding negotiations. Due to their specific focus on certain topics and indicators, these reports sometimes lack the interdisciplinary perspective that can be observed in the above-mentioned Special Reports of IPCC and IPBES. The "10 New Insights in Climate Science" reports address many of the challenges mentioned above, focusing on new findings from recent climate-related research. They are published annually and contains contributions from various disciplines (e.g. Martin et al., 2022; Bustamante et al., 2023). This series should be complemented by similar reports from other research areas related to the Earth system crisis.

Given the lack of such an integrative, annually published report focused on issues related to the biosphere, this publication summarizes recent advances in this field of research by addressing biosphere related challenges and bridging the time between the comprehensive assessment reports of IPCC and IPBES. Here, we define the biosphere as the global ecological system that includes all living organisms and their interactions. We have also integrated social and economic links to the biosphere. In doing so, it crosses the boundaries of the established sciences to provide an interdisciplinary view of the biosphere. Further, it will not be about repeating well-known findings such as drastically reducing fossil fuel emissions from all sectors, the biggest lever in the fight against climate change. Instead, this international collaboration aims to inform stakeholders and decision-makers about the latest policy-relevant, peer-reviewed, biosphere-related research findings. We further hope that it may inspire scientists to develop interdisciplinary questions and holistic solutions to pressing problems linking biosphere research, which includes biodiversity issues, to climate change and other anthropogenic stressorson the one hand and social and economic research areas on the other (e.g. Mahecha et al., 2024).

Here, we present eight recent and significant findings from biosphere research, based predominantly from peer-reviewed literature published since January 2022. Our topics present background information as well as challenges, and offer strategies for maintaining vivid ecosystems or enhancing degraded ecosystems and their services to human society. In addition, these topcis are gaining traction in the scientific community and stimulate future research questions. For each topic, not only the key findings are presented, but also the links and implications for related topics are emphasized, contributing to a comprehensive understanding of processes in the biosphere and their interactions with human systems.

We note that threats to coastal habitats (section 3.1), changes in the hydrological cycle due to changes in forest cover (section 3.2), and shifts in fire regimes (section 3.3) pose significant societal challenges that require transboundary cooperation for efficient and fair resource allocation and distribution. Climate change mitigation is expected to reduce many of these risks and associated costs . The effectiveness and risks of nature-based carbon dioxide removal is discussed in section 3.4 . In this context, adequate conservation measures in human-modified landscapes are key to maintaining nature's contribution to people (section 3.5). At the international level, interconnected and comprehensive policy packages are needed to address the root causes of environmental degradation and revitalize a just human-nature relationship (section 3.6). In the future, the socio-economic value of ecosystems will increase with rising real market incomes and the changing scarcities of ecosystems (section 3.7) For the local and regional level, we present convivial conservation principles which as aguiding strategy for coexisting with biodiversity within planetary boundaries (section 3.8).

With this study, we hope to raise awareness of the various challenges within the biosphere - emphasising links across environmental and socio-economic domains - and their interlinkages with other crises within the Earth system, to provide synergistic strategies for addressing complex challenges, and to stimulate future research questions.

2 Method

We followed a similar methodology to that used for the "10 new insights in climate change" (Martin et al., 2022). First, we set up an editorial board of experts from different fields of ecology, sociology and economics. Meanwhile, we issued an open call inviting the scientific community to submit thematic proposals for this review based on peer-reviewed publications not older than January 2022. The call for proposals (see Appendix A) was disseminated through social media, mailing lists and individual invitations. Despite our efforts to achieve global outreach, we anticipate that we may not have reached some important groups or that they may have chosen not to respond. Hence, this first synthesis has to be seen as a preliminary effort with caveats that

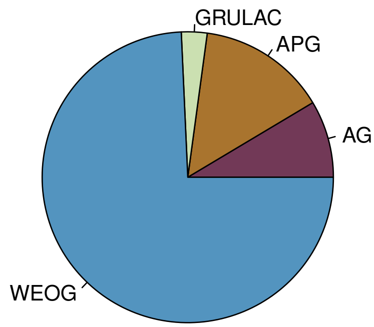

Figure 1. Origin of the authors from the geopolitical regional groups of member states of the United Nations: African Group (AG); Asia and the Pacific Group (APG), Latin American and Caribbean Group (GRULAC), Western European and Others Group (WEOG)

can be improved in the subsequent iterations. We expect that this approach is the first step towards future annual biosphere research synthesis reports that will evolve into more substantial, comprehensive assessments, with a larger pool of contributions from a more diverse and globally distributed group of researchers.

We initially received a total of 20 topic proposals. The editorial board made the final selection of based on the following criteria: (i) sufficient evidence from peer-reviewed publications in the last two years; (ii) emerging general consensus; (iii) relevance to international negotiations and decision-making processes.

The editorial board decision process consisted of two steps. First, each member independently rated the proposals on a scale of 0 to 10, with 0 being ’not recommended’ and 10 being ’highly recommended’. The issues were then discussed in a virtual meeting of the editorial board, starting with the highest-rated proposals. During the discussion, the board members could adjust their previous rating. Following internal discussion of authors and the review process, the editorial board’s original recommendation was reduced from 10 topics to eight by merging them.

Each topic was written by a team of two to five experts. These topic authors were selected by the editorial board based on their scientific expertise, as evidenced by their recent scientific publications. Diversity in terms of gender, geography, and scientific discipline was also considered (Figure 1, Table 1). We emphasize that there are differences between some perspectives and want to be open about the fact, therefore, not all authors necessarily support all of them and we emphasise that this collection does not claim to be comprehensive nor absolute.

Table 1. Web of Science research areas represented by the authors. Several research areas could be selected by one author.

research area	$\sum$	research area	$\sum$	research area	$\sum$
environmental sciences	23	biodiversity conservation	13	ecology	12
social science, interdisciplinary	9	geography	6	meteorology, atmospheric sciences	5
geosciences, multidisciplinary	4	remote sensing	4	agriculture, multidisciplinary	3
forestry	3	agricultural economics & policy	2	anthropology	2
computer science, interdis. appl.	2	economics	2	environmental studies	2
plant sciences	2	biology	1	cultural studies	1
engineering, multidisciplinary	1	ethics	1	marine & freshwater biology	1
mathematics, interdis. appl.	1	physics, applied	1	planning & development	1
political science	1	social issues	1	urban studies	1

3 Insights

3.1 Innovative and inclusive solutions offer opportunities to support coastal habitats under threat

3.1.1 Background

Coastal habitats mainly refer to mangroves, saltmarshes, seagrass beds and coral reefs, which are important ecosystems that provide resilience services such as fisheries that contribute to human well-being (Costanza et al., 2014; Trégarot et al., 2024). Coastal habitats are important for marine biodiversity (Trégarot et al., 2024) as they function as breeding grounds for fish (Nodo et al., 2023) and shelter for water birds. They sequester carbon at a much greater rate per area than most terrestrial ecosystems (e.g. mangroves sequester 174 gC $m^{-2} year^{-1}$ on average Alongi, 2012). Finally, they prevent coastal erosion, which protects human settlements.

3.1.2 Challenges

The importance of a healthy coastal habitat is well established (NOAA, 2024), but coastal ecosystems are under threat at concerning rates due to unsustainable development and climate change (IPCC, 2022c). For example, 35% of mangroves have been lost due to local drivers, but 50% of mangrove ecosystems are at risk of collapse due to climate change and local factors (Hagger et al., 2022). The widespread retreat of coastal habitat is likely to occur at warming levels greater than 1.5°C (Saintilan et al., 2023). 500 million people are projected to experience challenges (e.g. loss of food source) within decades due to the likely loss and degradation of coral reefs that they currently depend for food, tourism, or as coastal barriers (Hoegh-Guldberg et al., 2017). Global warming of 1.5°C to 2.0°C would double the area of tidal marsh exposed to 4 mm/yr of rising sea level by the end of this century. With 3°C of warming, nearly all of the world's mangrove forests and coral reef islands and almost 40% of mapped tidal marshes are estimated to be affected by this rice in sea level (Saintilan et al., 2023). Yet, each coastal habitat responds differently to climate change (Trégarot et al., 2024), making it important to consider local responses. The pressure on coastal habitats from climate change accumulates on top of other anthropogenic stressors such as overtourism, invasive species (Roy et al., 2024), land reclamation (Yamano et al., 2007), pollution (Wakwella et al., 2023), aquaculture, and development of hard infrastructure, making it a challenge to involve all relevant stakeholders.

3.1.3 Offering solutions

Research on nature-based solutions demonstrate co-benefits of biodiversity provides numerous co-benefits locally (e.g., ensuring livelihoods while increasing resilience to coastal hazards such as storms) compared to engineered solutions with hard infrastructure (which can be expensive and often can have negative consequences on habitats) (Hahn et al., 2023). This means that investing in the space to preserve and recover coastal habitats can help restore biodiversity, mitigate help to adapt to climate change, while also providing leisurely functions or a source of livelihood. Doing so improves resilience to a variety of identified hazards (such as coastal erosion, storms etc.) and restore a healthy environment (Hahn et al., 2023). Moreover, many stakeholders already prefer nature-based over gray infrastructure (Apine and Stojanovic, 2024). This was also the case in the Philippines for the "Bakhawan Mangrove Eco-Park" in Aklan province, which is widely considered a successful multispecies mangrove reforestation project, led by the local government and the Kalibo Save the Mangroves AssociationMarquez et al. (2024). Studies suggest that mangrove reforestation also provides great benefits for mitigation globally. Mangroves provide 60% more blue carbon benefit than afforestation on marginal tidal flats for the same area (study conducted on 370 restoration sites in various parts of the world) (Song et al., 2023). Utilizing the right mangrove species for the right location may further prevent retreat of the coastal zones, reduce impacts from storms on human settlements, and positively contribute to fishing , among other expected co-benefits (Sunkur et al., 2023). Similarly, recent studies point to the potential of coral reef restoration, combined with coral adaptation and climate change mitigation, to hold off mass coral deterioration and enable reefs to keep up with sea level rise of low to moderate carbon emissions scenarios (Toth et al., 2023; Webb et al., 2023).

Stakeholders have insufficiently considered locally relevant species when planning with nature-based solutions. For example, China introduced an invasive species called *Spartina alterniflora* (saltmarsh cordgrass) to reduce soil erosion and provide a number of other ecosystem services in 1979. Although successful in fulfilling its purpose, it occupies the niche of some local plant species (such as *Phragmites communis* and *Scirpus mariqueter*) and degrades the habitat of some species of water birds (Nie et al., 2023). Managing invasive species such as *Spartina alterniflora* can be costly and complex. Wise use of biomass can contribute to the local economy, prevent coastal erosion, and still benefit wildlife that depends on it. Hence, local species should be prioritized when vegetation re-establishment efforts are being planned to ensure greater co-benefits (e.g., when using mangrove or saltmarsh).

Mitigation of coastal habitat loss/degradation can be realized through management and restoration. In doing so, ensuring sustainable development, it is alsoimportant to take on a watershed approach to protect coastal habitats (e.g., preventing nutrient enrichment, coastal development, hydrological disturbances, anchoring or sedimentation (Trégarot et al., 2024)). Trade-offs and synergies between biodiversity conservation/restoration and other services such as carbon sequestration, coastal protection, water purification, aquaculture, and eco-tourism should be holistically considered. For example, dedicated locations where coastal habitats serve productive purposes and contribute to biodiversity conservation may hold a solution for socio-ecological balance.

Community involvement in coastal habitat restoration can increase willingness to participate in stewardship activities,thus improving biodiversity and climate change outcomes (Dean et al., 2024). As demonstrated by the nascent concept of "blue justice" that protests the marginalization of small-scale fishers (Isaacs, 2019), coastal stakeholders (incl. communities, Indigenous peoples, and small-scale fishers) have tended to be excluded from marine decision-making (Blythe et al., 2023) yet meaningful community engagement in projects can result in equitable and resilient project outcomes (Fox et al., 2023). Better allowing space for stewardship practices by Indigenous and local communities can provide meaningful lessons for societies across borders by ensuring livelihoods and biodiversity are restored or conserved (e.g., in California USA, Sanchez et al., 2023, See also section 3.5 & 3.8). New practices of restoring coastal habitats with co-benefits for people and nature have also been documented (e.g., nature reserve Zwin that consists of dunes, marshes and mudflats along the Belgian and Netherlands border open to tourists and the Mai-po Wetland in Hong Kong managed for the benefit of migrating birds, aquaculture and tourism (Cheung, 2011)).

Institutional mechanisms must align to enable innovative or unconventional practices. Institutional barriers to nature-based solutions are currently higher than for gray infrastructure (Jones and Pippin, 2022). Structural recognition of co-benefits of nature-based solutions (Apine and Stojanovic, 2024) could include project funding schemes that recognize the multiple benefits of restoring coastal habitats (e.g., beyond mitigating flood risks), incorporation of feedback from engaged stakeholders into the project design, and robust monitoring beyond the implementation phase (Palinkas et al., 2022). Researchers have also begun exploring the role of art in raising awareness around coastal sustainability (Matias et al., 2023). Institutional mechanisms also play an important role in jurisdiction. Coastal habitats are inseparable from upstream land-based activities. Integrated watershed management that transcends jurisdictional boundaries including through financing for long-term action can foster healthy coastal ecosystems (Wakwella et al., 2023, See also section 3.6).

3.2 Forest protection avoids worsening future droughts and keeps regional, seasonal rain patterns stable

3.2.1 Background

Climate change is altering rainfall patterns and intensity in the tropics (IPCC, 2012; Robinson et al., 2021; IPCC, 2022b, 2023) with implications for ecological and human water security. Also, changes in the seasonal variability in rainfall patterns across the tropics have been observed (Feng et al., 2013; Fu et al., 2013; Fu, 2015). Tropical forests can play a mitigating role of climate change not only because they take up almost half of fossil fuel emissions (Pan et al., 2024) but also through their key role in the global water cycle (Bonan, 2008). About 40% of the global land precipitation is estimated to originate from evapotranspiration (Ellison et al., 2017), which is regulated by vegetation cover.

The tropical water cycle is essential for the health of ecosystems, supports biodiversity, and maintains regional rainfall. (e.g., Makarieva and Gorshkov, 2007; van der Ent et al., 2010; Spracklen et al., 2012). High rates of evapotranspiration occur across the tropics due to a combination of intense radiation, large evaporation surface (the leaves, up to 10 m^2 leaves /m^2 ground) and high temperatures and significantly contribute to atmospheric moisture. For example, about one-third of the moisture in the Amazon Basin is recycled regionally with evapotranspiration from the Amazon forest specifically contributing to up to 70% of precipitation in some basins (van der Ent et al., 2010). Likewise, about half of the moisture in the Congo Basin is recycled regionally (Sorí et al., 2017; Staal et al., 2018; Tuinenburg et al., 2020). Furthermore, in tropical montane forests, interception of water from clouds is estimated to contribute by 5% of total precipitation in wet regions and up to 75% in dry regions (Bruijnzeel et al., 2011). This contributes to cloud formation and generation of rainfall patterns and other regional climatic conditions intricately linked to forest cover (e.g., Poveda and Mesa, 1997; Ellison et al., 2017). In South America, evaporated water is transported further across the continent, contributing to regional rainfall (e.g., Zemp et al., 2014, 2017). In some regions, this rainfall provides a large fraction of the water needed for rainfed agriculture (e.g., Zemp et al., 2014, 2017). In model simulations, deforestation in the tropics was shown to decrease cloud cover not only locally but also over extra-tropical regions (Luo et al., 2024).

3.2.2 Challenges

Despite efforts to curb deforestation, tropical forest loss has accelerated over the last two decades (Feng et al., 2022; Bourgoin et al., 2024). Several lines of research suggest that deforestation reduces regional and downwind rainfall, highlighting again the role of forests in sustaining regional hydrological cycles (Spracklen and Garcia-Carreras, 2015; Leite-Filho et al., 2021; Staal et al., 2023). Loss of forest cover disrupts transpiration and reduces precipitation, leading to a drier climate, reduced agricultural productivity and increased stream flow in large watersheds (Zhang et al., 2017; Zhang and Wei, 2021). In the Amazon basin, this has led to a measurable decrease in precipitation across South America (Lawrence and Vandecar, 2015). Across the whole tropics, a 1% reduction in forest cover is thought to have reduced precipitation by an average of 0.25 ± 0.1 mm per month over the past two decades (Smith et al., 2023). Deforestation in South America might delay the onset of the rainy season by 30-40 days compared to historical periods up to mid-century (Commar et al., 2023; Bochow and Boers, 2023). Modelling studies indicate that future deforestation in the Congo can reduce local precipitation by 8–10% in 2100 (Smith et al., 2023).Current Earth system models are known to underestimate water recycling in the tropical forests, especially in the Amazon (Baker and Spracklen, 2022). In this context, recent studies show that the coupling between the water cycle and vegetation is tightening in many regions across the globe such that LAI affects ET more strongly over time (Forzieri et al., 2020), and LAI gets more sensitive to soil moisture availability (Li et al., 2022). However, such an increase in water-vegetation coupling is not reported in the tropics so far.

Droughts during heat waves appear to be intensified by deforestation and can spread via teleconnections (Miralles et al., 2019; Staal et al., 2020). Droughts have recently increased in many tropical regions. For example, severe and exceptional droughts occurred in the Amazon region in 2005, 2010, 2015 and 2023 (e.g., Jiménez-Muñoz et al., 2016; Papastefanou et al., 2022). Other tropical rainforests have also been affected (Phillips et al., 2009; Lewis et al., 2011; Tao et al., 2022). Droughts can also lead to forest loss and thus cause a positive feedback with decreasing precipitation (Zemp et al., 2017; Bochow and Boers, 2023).

Uncertainty in the analysis of tropical water-vegetation interactions results from limited soil data and the challenges to estimate evapotranspiration using remote sensing techniques, due to dense vegetation. Therefore, hydrological datasets derived with machine learning techniques that extrapolate water variables in space are limited in the tropics (O. and Orth, 2021; Nelson et al., 2024). Due to these uncertainties, it is not yet clear when the tipping point at which the rainforest turns into a dryland or grassland will be reached. The reduced soil moisture as a result of deforestation would lead to severe dieback due to a drier climate (Lovejoy and Nobre, 2018), with severe consequences for the water and carbon cycle (Lenton et al., 2019).

In addition to impacts on natural systems, increasing droughts also result in increasingly heavy socio-economic losses. Globally, droughts are estimated to affect 1.8 million people and cost more than USD 307 billion each year (Thomas et al., 2024). For example, droughts in Africa are estimated to have affected almost half a billion people and resulted in 700,000 deaths from 1950 to 2021, with associated damages of about USD 6.6 billion (Ayugi et al., 2022). In Europe, economic consequences of drought have been estimated to cost about Euro 6.2 billion per year on average between 1991 and 2020, and even more for extreme droughts such as 2003 (8.3 billion Euro)(EEA, 2010). Future impacts of drought on critical infrastructure in Europe is expected to increase in the next years (Forzieri et al., 2018).

3.2.3 Offering solutions

Increased efforts are needed to halt deforestation, forest degradation, and accelerate forest restoration by 2030, as pledged in the New York Declaration on Forests and the Glasgow Leaders' Declaration on Forests and Land Use (Gasser et al., 2022). Particularly in areas with high rates of deforestation (Feng et al., 2022; Lapola et al., 2023; Climate Focus, 2023).

Protecting forests is essential to mitigating future droughts and maintaining stable seasonal rainfall patterns. Evidence indicates that deforestation arises from speculative land clearing, land tenure conflicts, transient agricultural practices, abandoned farmland, and agriculture-related fires encroaching on adjacent forests (Pendrill et al., 2022). Effective measures to curb deforestation require sustainable economic alternatives for intact forests (e.g. Griscom et al., 2020, see sections 3.8, 3.7), the establishment of protected areas, the enforcement of substantial penalties for illegal logging (e.g. Brancalion et al., 2018, see also section 3.5), and broader improvements in land governance and rural development (e.g. Latawiec et al., 2017; Bastos Lima and Persson, 2020). International supply chain interventions can help reduce tropical deforestation and forest degradation, but will be most effective if they target high-risk areas with initiatives that promote sustainable rural development and strengthen territorial governance (Pendrill et al., 2022). Indigenous peoples are also crucial to forest conservation, as their traditional land management practices have proven exceptionally effective in conserving forest ecosystems (Fa et al., 2020). Empowering indigenous communities and legally securing their land rights are, therefore, crucial to long-term conservation success.

Restoring degraded and deforested areas worldwide can increase precipitation and thus mitigate the reduction caused by forest loss (Hoek van Dijke et al., 2022, see also section 3.6). An increase in forest cover increases both precipitation and evapotranspiration. For instance, in the southern and eastern Amazon, reforestation could increase precipitation, which is critical given the risk of climate change-induced drying and a possible tipping point at which a forest transitions to a dryland or grassland due to decreased moisture (Zhao et al., 2017). Similarly, reforestation in middle America and SEA (including southern China) could largely offset projected drying, and Mediterranean Europe would also benefit from regional reforestation efforts. Additionally, afforestation have also an impact on low cloud cover in Europe (Caporaso et al., 2024). Furthermore, due to moisture-recycling of forests, reforestation in the south-eastern Amazon would increase gross primary productivity (Staal et al., 2023).

Yet, afforestation for carbon sequestration in savannahs and other naturally tree-poor ecosystems can disrupt local water balances and biodiversity (Veldman et al., 2015; Fernandes et al., 2016). Trees often use more water than grasslands, which can lower the water table and reduce the availability of water for other plants and animals native to these areas. This change can lead to the drying up of wetlands and lesser water flows in streams and rivers (Farley et al., 2005; Lalonde et al., 2024), impacting species that are adapted to specific water regimes. Moreover, the planting of non-native tree species can alter soil properties and inhibit the growth of native vegetation, which relies on fire and open sunlight conditions to thrive (see section 3.3). These ecological shifts can diminish the natural resilience of these ecosystems, making them less adaptable to climatic changes and more susceptible to invasive species. Therefore, while afforestation in certain contexts can be beneficial for carbon sequestration and local societies, it requires careful planning and management to avoid unintended ecological consequences (Farley et al., 2005).

More and more accurate data on vegetation and water could be collected through more standardised and harmonized way, as often water-related perspective Furthermore, there is a need for more regionally distributed ground-based measurements and monitoring, covering underrepresented biomes and vegetation types, e.g. the tropics and semi-arid regions, and providing morecountry or regional detail, which is crucial to understand region-specific feasibility. Further, future satellite missions using longer wavelengths such as SAR L-band (Lal et al., 2023) or P-band missions (Garrison et al., 2024), although the use of the latter is restricted by the military in many areas. This can provide a basis for more accurate observation-based analysis and better constrain state-of-the-art models to quantify better the large-scale pan-tropical effect of afforestation or deforestation on the hydrological cycle (see also Doelman et al., 2020; Koch and Kaplan, 2022; Yu et al., 2022). Consequently, this can also contribute to a more accurate understanding and estimation of increasing, and often unexpected, trends in tree mortality globally (Hartmann et al., 2022).

3.3 Delayed climate change mitigation likely to increase fire risks in many regions

3.3.1 Background

Fire is a natural phenomenon that has shaped many ecosystem types worldwide and contributed to their biodiversity (Bond and Keeley, 2005; Pausas and Keeley, 2009; Bowman et al., 2011; He et al., 2019). Humans have altered fire regimes by utilizing fire and changing the landscape, and also by suppressing fires to avoid its destructive consequences (Bowman et al., 2011). However, unprecedented record wildfires have recently affected different parts of the world. In 2023, 7.8 million ha burned in Canada (MacCarthy et al., 2024), and Greece experienced the largest fire ever recorded in Europe, burning more than 93,000 ha (Jones et al., 2024), raising concerns about future fire dynamics.

Many factors affect fire regimes, but recent research suggests that two major factors - human activities (including land-use change) and meteorological fire danger - are pulling in opposite directions. On the one hand, human factors, in particular agricultural expansion and intensification in African savannas, grasslands and shrublands biomes, have caused a decrease in burned area of these biomes by 13% over the last two decades (Jones et al., 2024; Andela et al., 2017; Jones et al., 2022; Chen et al., 2023). On the other hand, increasing fire weather severity and decreased snow cover have increased burned area and fire intensity in high-latitude regions, e.g. burned area has increased by 58 % since 2002 in the North American boreal forest biome (Jones et al., 2024), albeit with large regional variability (Bedia et al., 2015; Jones et al., 2022; Chen et al., 2023; Cunningham et al., 2024; Hessilt et al., 2024). Across the globe, the two factors may change individually or in conjunction. So against a backdrop of globally decreasing burned area, some areas are experiencing increasing extreme fire seasons (Brown et al., 2023; Cunningham et al., 2024) and so-called 'extreme fires' or 'megafires' (San-Miguel-Ayanz et al., 2013; Collins et al., 2021) which are large, intense and difficult to control, become more frequent (2.2-fold global increase since 2003 (Cunningham et al., 2024)).

These megafires exceed natural fire regimes and are extremely detrimental to biodiversity (Leeuwen et al., 2023), human infrastructure, air quality (Xu et al., 2023) and carbon stocks (Clarke et al., 2022; Copernicus, 2023; Zheng et al., 2023). In 2023–2024, carbon emissions from wildfires increased globally by 16% above the long-term average (Jones et al., 2024). While emissions from African savannas slightly declined, this reduction was insufficient to counterbalance the substantial rise stemming from extreme fires in Canada's boreal forests (MacCarthy et al., 2024), where carbon emission anomalies reached nine times above average (Jones et al., 2024).

3.3.2 Challenges

Analyses of fire trends and future projections show strong climate-change-induced increases in fire weather severity across most of the world (Abatzoglou et al., 2019; Jones et al., 2022; Jain et al., 2022). This poses a significant challenge for society, particularly forestry and civil protection. 2023 was a year of extensive civil protection efforts. In Canada alone, over 230,000 people were evacuated due to wildfires. However, the scale of these efforts often exceeded capacity with negative consequences for fire suppression, as seen in civil protection efforts in Greece (Jones et al., 2024). Furthermore, millions of civilians were exposed to smoke; during the Canadian fires, around 50 million people suffered from health-threatening air quality (Wang et al., 2024; Yu et al., 2024). However, the problem is highly heterogeneous, with already fire prone areas experiencing increased risk of extreme weather conditions (Scholten et al., 2021; Brown et al., 2023; Cunningham et al., 2024), but also fire-prone conditions emerging in relatively cooler and wetter areas that have been little affected by fire so far, e.g. boreal and temperate zones and mountains (Cunningham et al., 2024; Jones et al., 2022; Hetzer et al., 2024).

These challenges are heightened by local factors relating to ignition, vegetation, and land cover, which can play a major role in increasing fire danger. In some regions, land cover is characterised by highly flammable species such as pine, spruce, and eucalyptus, and planted in large and homogeneous stands, which can promote fire spread. For one of the largest wildfires in central Europe, where Norway spruce monocultures suffer heavily from bark beetle attacks since the exceptional drought of 2018, it has been shown that burn severity was highest in dead spruce stands (Beetz et al., 2024). For fire risk assessments, both climatic and non-climatic factors need, thus, to be considered (European Environment Agency, 2024).

Changing fire regimes also threaten large carbon reservoirs but with regionally unique consequences. In the humid tropics, intact forest and peatlands are threatened by deforestation fires (Andela et al., 2022; Chen et al., 2023) and wildfires exacerbated by climate and land-use change (Turetsky et al., 2015; Harrison et al., 2020). High-latitude peatlands in remote areas are vulnerable to large, long-lasting fires burning through deep peat layers (Scholten et al., 2021; Nelson et al., 2021), which are not actively controlled and lead to large carbon losses (Turetsky et al., 2015). Future stocks from potential 'nature-based solutions' may also be vulnerable to wildfires, undermining climate mitigation efforts. However, long-term predictions of fire risk that could be incorporated into planning still include large uncertainties at the local scale (Hantson et al., 2020). See also section 3.2 and 3.4.

3.3.3 Offering solutions

Decreasing trends in burned area in regions where the fire weather has become more severe, such as non-Mediterranean Europe (Jones et al., 2022), clearly show that fire risks can be mitigated, although at increasing cost (Bayham et al., 2022). However, the costs of fire mitigation are surpassed by losses, especially for extreme fire seasons (Bayham et al., 2022) and comparable to other climate change mitigation costs (Phillips et al., 2022). Several studies emphasize that the burned area is negatively related to the Human Development Index at both global (Chuvieco et al., 2021; Teixeira et al., 2023) and continental scale (Forrest et al., 2024). This demonstrates that more economically developed societies tend to reduce their burnt area, either due to effective fire prevention measures or because of rapid and successful firefighting (see also section 3.6). Whilst this broad picture is encouraging, it is important that this view is tempered with the knowledge that relying on fire suppression as a sole strategy is risky and potentially counterproductive, as it can increase fuel accumulation and, therefore, fire severity (Kreider et al., 2024). A clear example of this is the forests of the United States where, despite a high level of economic development, burnt area is increasing (Iglesias et al., 2022; Chen et al., 2023). Whilst climate change plays a important role in this trend (Iglesias et al., 2022; Burton et al., 2024), a very effective strategy of fire suppression over the 20th century (Magerl et al., 2023) without a sufficient fuel reduction strategy has led to current levels of very high fuel accumulation. These high fuel loads contribute to the current crisis, a phenomenon anticipated over 50 years ago (Dodge, 1972).

Strategies should be developed targeting risks at local, national, and regional levels (Chuvieco et al., 2023). Locally, fire suppression can be aided by introducing fire breaks and access points, particularly roads (Haas et al., 2022). However, this solution should be cautiously applied as land fragmentation also negatively affects species richness (Willmer et al., 2022). Fuel reduction techniques might also be considered, including mechanical or grazing, but prescribed burning might also provide a more natural solution also useful for maintaining fire-dependent vegetation types and biodiversity (Neidermeier et al., 2023). Moreover, fire suppression should be limited in areas where regular low-intensity fires play a vital role in naturally clearing fuels. There, maintaining fires as a part of the ecosystem can reduce the risk of more severe fires from excessive fuel accumulation. National strategies should promote biodiversity because this also promotes fire resilience by avoiding monocultures of highly flammable species. Furthermore, studies have shown that cross-border collaborations are necessary and effective for allocating resources efficiently and minimizing risk (Bloem et al., 2022). International cooperation can benefit from comprehensive 'fire-smart' solutions, such as those recently targeted in the EU Green Deal (Ascoli et al., 2023; Regos et al., 2023). A number of cases document the value of incorporating Indigenous knowledge and governance into fire management strategies in Latin America (Oliveira et al., 2022), Africa (Croker et al., 2023), North America (Connor et al., 2022), and Australia (Legge et al., 2023). See also sections 3.6, 3.8.

3.4 Nature-based Carbon Dioxide Removals (CDR) implementation risks

3.4.1 Background

A key intersection point between ecology and climate change research is the role of terrestrial ecosystems in exchanging carbon between terrestrial and atmospheric carbon pools. Human activities are affecting these carbon exchanges directly via deforestation and other land-use activities, as well as indirectly via the response of terrestrial ecosystems to elevated CO_2 and resulting changing climate conditions (Friedlingstein et al., 2023; IPCC, 2021). Direct effects ,including deforestation, forest regrowth and other land-use activities, currently produce net emissions to the atmosphere of about 4 billion tonnes of CO_2 per year (about 10% of global fossil fuel emissions), which includes an estimated removal flux from reforestation activities of 2 billion tonnes of CO_2 per year. Indirect carbon fluxes, resulting from processes like CO_2 fertilization and changing growing season length, currently absorb about 12 billion tonnes of CO_2 per year; this indirect carbon sink shows interannual variability, though has consistently represented an absorption of close one-third of annual fossil fuel CO_2 emissions over the past several decades (Friedlingstein et al., 2023; IPCC, 2022a).

3.4.2 Challenges

Given the current role of the terrestrial biosphere as a net carbon sink (the net of direct emissions and indirect uptake), there is considerable interest in pursuing strategies to enhance nature-based carbon dioxide removal (CDR) to contribute to climate mitigation efforts. Many studies have highlighted the potential of nature-based CDR (Griscom et al., 2017; Fuhrman et al., 2023) as a key component of a range of potential CDR options.

Reforestation and afforestation are typically seen as the largest potential contributors. However, nature-based CDR also includes strategies such as biochar and other agricultural management practices to increase soil carbon sequestration. Many concerns about nature-based carbon removal have also been raised in recent literature however, including whether a focus on CDR in research and policy discussion could lead to delays in fossil fuel emissions reductions (Carton et al., 2023), as well as whether nature-based CDR has a large enough potential to be a meaningful contribution to climate change mitigation goals (Roebroek et al., 2023). Parr et al. (2024) also highlight an important concern that reforestation with non-native tree plantation species could lead to theloss of native ecosystems that may negate any carbon-related gains, supporting previous findings that more biodiverse forests are better at capturing and storing carbon (Liu et al., 2018b; Wessely et al., 2024). These and other concerns highlight a growing understanding that nature-based CDR must be undertaken with attention to local ecosystems and community needs (Seddon, 2022), and that nature-based CDR should in all cases be treated as a complement (and not an alternative) to fossil fuel CO_2 emission reductions Matthews et al. (2022).

Nature-based CDR, particularly in the case of its use as an offset for fossil fuel CO_2 emissions faces a number of known and well-understood challenges. These challenges include: (i) accounting: accurate measurement of forest carbon accounting, including removal and storage; (ii) additionality: an assessment of whether the removal would have occurred in the absence of offset financing; (iii) leakage: an analysis, which examines whether the intervention displaces land-use activities, resulting in emissions elsewhere; (iv) durability: the risk of reversal analysis, which considers the longevity of carbon storage; (v) environmental justice: which examine whether the carbon removal efforts amplify existing inequalities and injustices; (vi) and finally non-climate effects: for instance, changes in albedo or other biophysical effects. (Carton et al., 2021; Haya et al., 2023; Groom and Venmans, 2023; Hasler et al., 2024).

The durability challenge associated with nature-based carbon storage has been of particular concern in recent years owing to increases in natural disturbances (as discussed in section 3.3). Climate-driven changes in wildfire and other natural disturbance regimes have considerable potential to lead to increased the future vulnerability of land-based carbon stocks with continuing climate change (Anderegg et al., 2020). Furthermore, the permanence of land carbon storage can also be compromised by changing human disturbance pressures, including those emerging from potential uses of biomass as an energy sources in climate mitigation strategies is that land carbon pools are vulnerable to disturbances, either from natural processes (such as fire) or human pressures (such as deforestation). Furthermore, climate-driven changes in wildfire and other natural disturbance regimes have the potential to lead to increased vulnerability of land-based carbon stocks with continuing climate change (Anderegg et al., 2020).

The potential for land-based carbon storage to be temporary evokes a particular accounting challenge when used as an offset for fossil fuel CO_2 emissions, which represent a permanent transfer of new carbon from a geologic reservoir into the atmosphere-land-ocean carbon system. Concerns of impermanence (or risks of reversal) are a key concern associated with the application of nature-based carbon storage as a contributor to climate mitigation efforts (Zickfeld et al., 2023). However, even temporary carbon storage does have climate value, and in particular, has been shown to decrease peak warming if coupled with ambitious fossil fuel emission reductions (Matthews et al., 2022).

3.4.3 Offering Solutions

One solution to the challenge of the durability of land carbon storage may be to treat all nature-based carbon removal and storage as a temporary quantity and to explicitly account for the amount of time the carbon remains in storage as part of its climate value. Matthews et al. (2023) proposed a new application of tonne-year accounting to measure the time-integral of land carbon removal and storage as a way of tracking the climate benefit of temporary storage. Previous applications of tonne-year accounting have focused on trying to equate temporary and permanent storage, leading to strategies such as vertical stacking of offset credits to claim that a given amount of temporary storage is equivalent to a unit of permanent storage (Haya et al., 2023). This previous use of tonne-year accounting has been criticized in the literature given that it is not grounded in any physical climate science relationship, and leads to a false equivalency of temporary and permanent storage that could further disconnect carbon offset calculations from the scientific understanding of carbon stocks and flows in natural systems (Levasseur et al., 2012; Brander and Broekhoff, 2023).

However, Matthews et al. (2023) showed that a reimagined approach to tonne-years could effectively track nature-based carbon storage over time. Furthermore, they showed that tonne-years of temporary carbon storage are proportional to degree-years of avoided warming (i.e., the time integral of the temperature change caused by temporary storage), providing an approach to measure the climate effect of temporary carbon storage in a way that is coherent with scientific understanding (Matthews et al., 2023). Measuring and quantifying the time dimension of nature-based carbon storage and treating carbon offset as a time-share rather than a single purchase (e.g., by using horizontal stacking to guard against loss over time) could be an important improvement to current carbon offset protocols (Haya et al., 2023).

3.5 Sustaining Nature's Contributions to People in human-modified landscapes requires at least 20%–25% (semi-)natural habitat per square kilometer

3.5.1 Background

Biodiversity is declining faster than ever with global wildlife populations declining by an average of 73% over the last 50 years (WWF, 2024). Around 1 million animal and plant species are now threatened with extinction despite decades of increased conservation investment to bend the curve of biodiversity decline (Leclère et al., 2020). This decline is mainly driven by changes in land and sea use, overexploitation of resources, pollution, invasion of exotic species, and climate change (IPBES, 2019). Such decline is also associated with the expansion of global systems of extractivism in recent centuries, which contrasts sharply with earlier patterns of stewardship (Ojeda et al., 2022; Molnár et al., 2024, see also section 3.8).

The conversion of natural habitats has provided benefits by creating more space for agriculture, housing and industry, but at a significant cost to biodiversity, reducing the area of natural ecosystems by about half, with agriculture alone occupying 38% of the Earth's land surface (FAO, 2023). Currently, only 16.64% of terrestrial areas and 8% of marine areas are protected, many of which are not fully ecologically representative or effectively managed, while about 75% of the terrestrial environment and about 66% of the marine environment have been significantly altered by human activities (IPBES, 2019) . This habitat conversion jeopardises valuable ecosystem functions and beneficial contributions, such as healthy and sustainable food production, clean air and water, and recreational spaces, among others. For example, over 75% of global food crops rely on animal pollination, but pollinator populations are declining due to habitat loss, pesticides, and climate change (IPBES, 2019).These contributions, known as ecosystem services or Nature's Contributions to People (NCP), directly or indirectly contribute to human well-being, economic stability, and overall quality of life (Díaz et al., 2018, see also section 3.1 and 3.2).

3.5.2 Challenges

Biodiversity has multiple dimensions, making it challenging to define synthetic policy objectives and metrics or to track progress (Díaz et al., 2020). Most conservation efforts focus on halting the conversion of remaining intact natural ecosystems, and safeguarding their unique species as articulated in Goal A of the Kunming-Montreal Global Biodiversity Framework (Watson et al., 2018; Allan et al., 2022). However, human-modified lands and waters, which cover approximately half of the global Earth surface (IPBES, 2019), including highly managed agricultural fields and urban green spaces in mixed mosaic landscapes where natural functions are limited to small habitat patches, are often overlooked in conservation policies and global targets setting (Pollock et al., 2020), despite their critical roles in maintaining and supporting human well being and sustainable food production (Goodness et al., 2016; Díaz et al., 2018). The close proximity and relationship between people and biodiversity in these areas makes their contributions to human well-being even more important. Identifying metrics to ensure continuous contributions of such nature to human well-being is challenging due to the highly context-specific conditions under which biodiversity supports ecosystem functions (e.g., section 3.2). Yet, few proposals for the post-2020 Global Biodiversity Framework (GBF) explicitly address human-modified lands or the role of functional biodiversity in maintaining a good quality of life for all people (Rounsevell et al., 2020; Maron et al., 2021; Hammoud et al., 2024).

NCP provisioning in human-modified landscapes relies on the amount, quality, and spatial arrangement of habitat fragments and their accessibility to beneficiaries (Garibaldi et al., 2021; Priyadarshana et al., 2024). These landscape components serve as proxy measures for the functional integrity of ecosystems (Rockström et al., 2023; Mohamed et al., 2024). Evidence suggests that many NCP can be maintained by habitat within highly human-modified landscapes as long as a minimum level, quality, and distance to biodiversity is present, and/or the functional integrity is retained or rebuilt (Martin et al., 2019; Eeraerts, 2023; Mohamed et al., 2024). The required habitat levels for NCP provisioning vary depending on the context, the NCP, thedemand for it, the landscape type and the taxa involved making it difficult to assess direct relationships (Garibaldi et al., 2011; Cariveau et al., 2020). Nonetheless, below a certain threshold nature can no longer provide a majority of benefits (Rockström et al., 2023).

A recent systematic review of 154 studies found that the capacity of human-modified lands to pollinate crops, regulate pests and diseases, maintain clear water, limit soil erosion, and maintain recreation spaces for people declined significantly and often disappears when habitat area falls below 20%–25% per km^2, and nearly disappeared below 10% habitat per km^2 (Mohamed et al., 2024). Alarmingly, only one third of global human-modified lands are above the 20%-25% per km^2 level to sustain NCP provisioning, emphasizing the urgent need for policy interventions to restore and regenerate ecosystem functions and their benefits in the remaining two thirds of global human-modified lands (Mohamed et al., 2024).

The proposed minimum habitat levels can serve as a general guide to identify priority locations for conservation and restoration in support of sustainable NCP provisions. However, uncertainties remain about the successful implementation of these minimum habitat levels in practice due to factors such as climate change, habitat loss, unsustainable agriculture, and human settlement expansion, which complicate the implementation and may create trade-offs. General estimates and targets for land management are important, but often oversimplify the complexity of local conditions and can misrepresent the needs of local communities due to the inherent biases in ecological research that may not account for all biomes or ecosystem functions (Martin et al., 2012; Manning, 2024). Additionally, these metrics often overlook finer-scale NCP,such as those provided by soil biodiversity, and ignore the important role of complementary agricultural practices such as no-tillage farming, cover cropping, and leguminous rotations which can reduce erosion, nutrient loss and maintain biodiversity (Blanco-Canqui et al., 2015; Skaalsveen et al., 2019; Guinet et al., 2020; Rakotomalala et al., 2023). Current remote-sensing technologies also struggle to detect small and linear habitat elements or to differentiate complex landscape types, likely leading to underestimations of the current state of (semi-)natural habitats globally (Lechner et al., 2009; Jurkus et al., 2022). Therefore, allocating 20-25% of each square kilometre to (semi-)natural habitat within human-modified lands using general estimates, without proper management and consideration of local socio-economic priorities and ecological needs can lead to significant social and economic challenges. These include high restoration costs, land tenure issues, policy constraints, lack of expertise and knowledge, and potential conflict with the provision of material NCP, which might compete with food production ambitions and local community needs (e.g., housing), is negatively affecting the well-being of local people relying on those NCP (Mohamed et al., 2024).

3.5.3 Offering solutions

The implementation of such strategies effectively necessitates adapting and adopting practices best suited to local context and conditions, rather than prescribing a single practice to be applied globally. Restoration could, for instance, prioritize areas where habitat additions align with community needs and minimize trade-offs with food production. Countless context-specific strategies exist to enhance NCP provisioning and can be implemented in ways that create more synergies than trade-offs and support food security, livelihood and overall human well-being without compromising local resources (Jones et al., 2023; Rakotomalala et al., 2023). For example, Torchio et al. (2024) show that wild pollination is sustained when semi-natural cover is 20% per km^2. Further, modern agroecological practices and nature-based solutions, including diverse crop rotations and mixed cropping systems maintain habitat heterogeneity and promote ecosystem resilience (Lichtenberg et al., 2017; Shah et al., 2021; Ewert et al., 2023; Tscharntke et al., 2024). Agroforestry systems enhance soil health, water retention, and global carbon sequestration (Zomer et al., 2022; Fahad et al., 2022). Strategically incorporating habitats such as hedgerows, no-mow zones around field margins or other practices (M'Gonigle et al., 2015; Marja et al., 2022; Maskell et al., 2023) combined with innovations such as precision agriculture practices can maintain biodiversity (Arroyo-Rodríguez et al., 2020; Knapp et al., 2023) while optimizing agricultural productivity (Balafoutis et al., 2017). Protecting green spaces and parks in cities can enhance physical and mental well-being (Konijnendijk, 2023), and planting vegetation buffers along waterways can capture sediment and pollutants, among many other tools (Luke et al., 2019).

To implement this approach, it is essential to enhance tools and methodologies for identifying and quantifying key NCPs at the landscape scale. This includes determining the locally specific quantity (20–25% per km^2), composition, and spatial configuration of habitat elements required for effective NCP provisioning. To avoid conflicts, partnerships with diverse stakeholders - such as indigenous peoples, local communities, scientists and NGOs - should be prioritised in decision-making. These groups offer valuable, practical solutions for halting and reversing the loss of NCPs and promoting sustainable conservation efforts. In addition, resources must be reallocated to promote innovations in agriculture, production systems and urban planning that prioritise biodiversity.

The 25% of high-functioning nature per square kilometer offers a key policy tool, as it is the first widely applicable measurement of the minimum level of human-modified land that needs to be in a (semi-)natural state across several NCP and a wide range of landscapes. This proposed habitat level is the minimum level, not the optimal level required to meet adequate NCP demand (Mohamed et al., 2024). This habitat threshold reflects an approach that harmonizes human activities with ecosystem integrity, focusing on integration rather than strict separation between human and nature. It serves as a general guideline synergizing with existing policy targets (e.g., UN Decade on Restoration) for prioritising conservation initiatives and formulating adaptive, scalable policies beyond natural areas. See also Section 3.6, 3.8.

3.6 Interconnect and deliver comprehensive policy packages to address the root causes of degradation and revitalized, just human-nature relationships

3.6.1 Background

Today's dominant production and consumption patterns are far from achieving the Convention on Biological Diversity (CBD) 2050 vision of "living in harmony with nature,". Even under the "most sustainable" climate scenarios (SSP1, RCP 2.6), biodiversity loss continues at an alarming rate, with over 75% of terrestrial ecosystems significantly altered by human activity and more than 85% of wetlands lost since the pre-industrial era (Pereira et al., 2020b, 2024). While global efforts focus heavily on achieving climate targets, this emphasis undermines our shared life-support systems and overlooks opportunities to synergize human-nature relationships and reverse alarming biodiversity trends while addressing climate impacts (Obura et al., 2023; Kim et al., 2023).

Addressing these challenges requires a paradigm shift toward sustainable practices. Restoration efforts have demonstrated substantial ecological and economic benefits, with reforestation initiatives capable of sequestering up to 200 Gt of CO_2 over the next century (Chazdon et al., 2020) , while wetland rehabilitation can reduce flood risks by 35% in vulnerable coastal regions (Meli et al., 2017). The increasing adoption of "nature-positive" business strategies reflects a shift towards circular economy models, emphasizing waste minimization, resource efficiency, and closed-loop systems. For example, circular economy initiatives have the potential to reduce global resource extraction by up to 28% by 2050, aligning economic activities with planetary boundaries and fostering resilience against environmental degradation and climate change (Bocken et al., 2019; Korhonen et al., 2018; Lüdeke-Freund et al., 2019). Effective policy integration and international cooperation are critical to mitigating environmental degradation and incentivizing sustainable economic growth. Despite ambitious global agreements, biodiversity financing remains insufficient, with a current annual funding gap of approximately USD 700 billion needed to meet global conservation targets (Leal Filho et al., 2019; IPCC, 2023; Rockström et al., 2017; Steffen et al., 2018). Strengthening governance frameworks that simultaneously address climate, biodiversity, and resource management goals is essential to reversing ecosystem decline while maintaining economic stability (Rockström et al., 2017; Steffen et al., 2018).

3.6.2 Challenge

Current global trade structures often exacerbate environmental and social inequalities, disproportionately affecting developing countries with weaker regulations (Newell and Taylor, 2022). Industrial agricultural practices and resource extraction have a devastating impact on the biosphere that exceeds even the direct effects of climate change. For example, agricultural expansion accounts for approximately 80% of global deforestation, with the Amazon rainforest alone losing over 17% of its total forest cover since 1970, primarily due to cattle ranching and soybean cultivation (Barlow et al., 2018; Köhler et al., 2019). This environmental degradation is accompanied by social displacement, as an estimated 250 million people, primarily Indigenous and rural communities, are at risk of being forced from their lands due to large-scale land acquisitions and resource extraction projects (Hickel, 2020; Sánchez-Bayo and Wyckhuys, 2019; Jaureguiberry et al., 2022, see also section 3.4, 3.5). This phenomenon, known as 'telecoupling', highlights the interconnectedness of distant economic activities and their environmental impacts (Liu et al., 2018a). Several studies demonstrate this telecoupling: for instance, the global demand for palm oil has driven the loss of 56% of Borneo's lowland forests since 1985, leading to a 50% decline in orangutan populations Meijaard et al. (2020). Similarly, mining in Africa has led to the contamination of over 20% of freshwater resources in affected regions, impacting both human health and biodiversity Northey et al. (2017); Mancini et al. (2021) . In this context, while lithium extraction raises environmental concerns such as water depletion —wherein lithium brine mining in the Atacama Desert consumes up to 65% of the region's freshwater—it is generally less harmful than large-scale fossil fuel extraction, which contributes to 73% of global greenhouse gas emissions (Vikström et al., 2013; Krishnan and Gopan, 2024). Moreover, lithium mining's impact on local water sources is significantly lower than that of coal mining, which is responsible for approximately 10% of global freshwater pollution. Enhancing lithium recycling from spent batteries, which currently has an efficiency of only 5%, could significantly reduce the need for new mining operations and mitigate environmental damage (Geissdoerfer et al., 2017).

Effective biodiversity governance faces significant challenges, including the lack of platforms to set norms, address injustices and enforce accountability (Raja et al., 2022). These problems are often rooted in exploitative practices and colonial legacies as seen in cases where biodiversity-rich regions are overexploited for global markets without fair compensation for local communities. For example, only 1% of the profits from global biodiversity-derived pharmaceutical products return to the countries of origin, despite the fact that 70% of these compounds originate in the Global South (Atanasov et al., 2021). Revitalising the relationship between people and nature and fostering collective action are essential to halting biodiversity loss and restoring ecosystems.

Therefore, understanding global trade networks and their impacts is crucial to develop fair and sustainable integrated policies and international cooperation. Current projections suggest that adopting circular economy principles — such as reducing raw material extraction and increasing material reuse — could decrease global resource extraction by 28% and reduce waste generation by up to 39% by 2050 (Wiedmann and Lenzen, 2018; Wiedmann et al., 2020; Leal Filho et al., 2019; IPCC, 2023; Meli et al., 2017; Chazdon et al., 2020; Geissdoerfer et al., 2017).

3.6.3 Offering solutions:

Integrated policy packages should integrate environmental, economic and social policies to address the root causes of biosphere degradation and pollution and to mitigate climate change, while promoting sustainable practices such as the promotion of renewable energy and the enhancement of carbon sinks and conservation of ecosystems (Litvinenko et al., 2022; Ikram et al., 2022; Tedesco et al., 2022; UNEP, 2022; Ostrom, 2009, e.g., see also section 3.5). Measures include stricter regulations on resource extraction, the adoption of cleaner technologies and incentives to restore ecosystems. Policies such as the European Green Deal are examples of comprehensive frameworks that align climate action with economic and social objectives (Commission, 2019). International cooperation is also crucial to harmonise efforts across borders and prevent environmental damage from being displaced. For example, the Paris Agreement demonstrates the potential of global commitments to reduce carbon emissions and promote sustainability (UNFCCC, 2018; Steffen et al., 2018).

International environmental agreements with improved compliance mechanisms and accountability are crucial for strengthening global environmental agreements. Lessons learnt from international human rights agreements, such as the integration of accountability measures, can improve compliance with biodiversity commitments such as the Convention on Biological Diversity (CBD) (Koh et al., 2022).

Sustainable trade policies should be enforced through certification schemes such as the Forest Stewardship Council (FSC), the Marine Stewardship Council (MSC) or Fair Trade International for goods. Control mechanisms such as the EU Deforestation Regulation (EUDR), which aims to reduce illegal deforestation, are another lever. Incentives such as tax breaks or subsidies should also encourage companies to adopt sustainable practices, minimise waste, conserve resources and reduce emissions (OECD, 2020).

Transnational conservation collaborations such as the Amazon Cooperation Treaty Organisation (ACTO) and Africa's Great Green Wall project demonstrate the value of multinational approaches to conservation. These initiatives focus on combating deforestation and wildlife trafficking, restoring degraded lands and supporting local communities. Such projects show how regional cooperation can protect critical ecosystems and promote sustainable livelihoods (UNCCD, 2016; Fernandes et al., 2024).

Although there are several promising policies packages, like those presented above, they have to be developed further and applied from international to local scale: Such future policies should adopt frameworks that integrate multiple values of biodiversity, promote cross-sectoral actions, and ensure stakeholder participation. Locally tailored solutions and scalable approaches are necessary to restore ecosystems and foster positive outcomes for nature and people. Progress should be tracked through innovative biodiversity monitoring and adaptive management that incorporates Indigenous and local knowledge systems.

The following framework by Perino et al. (2022) promises to improve future action reversing current trends of degeneration of the biosphere: (i) The identification process for locally suitable actions and the promotion of stakeholder ownership must recognise the multiple values of biodiversity (Pascual et al., 2023; Martin et al., 2024) and account for remote responsibility. (ii) Cross-sectoral implementation and mainstreaming of biodiversity considerations need scalable and multifunctional approaches to restoring ecosystems and aim for positive futures for nature and people. (iii) Assessment of progress and adaptive management needs to be informed by novel biodiversity monitoring and modeling approaches that address the multidimensionality of biodiversity change, including the incorporation of Indigenous and local knowledge (e.g. in Gielen et al., 2024).

The Nature Futures Framework (NFF) supports collaborative decision-making by recognizing diverse values of nature and exploring shared pathways toward sustainable futures (Pereira et al., 2020a; Kim et al., 2023; IPBES, 2023). It emphasizes adaptive management and scenario analysis to plan for positive synergies between biodiversity conservation and climate action. Immediate actions include: (i) Integrating plural values and engaging diverse stakeholders in decision-making processes. (ii) Mainstreaming biodiversity conservation into all sectors. (iii) Using nexus approaches to address interlinkages, co-benefits, and trade-offs. (iv) Improving policy coherence and integration. (v) Applying best practices in ecosystem restoration and management (see also Pörtner et al., 2021a).

The implementation of global environmental policy packages requires an equity lens and a rights-based approach, as projects that are aligned with local people's preferences and through inclusive governance are likely to have more effective social and environmental outcomes (Obura et al., 2023; Löfqvist et al., 2023; McDermott et al., 2023). In addition, unpacking elements of social and environmental justice, including procedural, recognitional and distributive dimensions, is needed to support long-term transformation towards sustainability (Leach et al., 2018; Pereira et al., 2023). Indigenous peoples and local communities are leading by example by managing the biosphere in ways that support ecological integrity and thus biodiversity conservation (Garnett et al., 2018; Dawson et al., 2024; Seebens et al., 2024; Massarella et al., 2021), see also section 3.6 and 3.8).

Integrating biodiversity into global trade policy ensures that efforts to protect the environment are coordinated and effective across borders. These interlinked actions provide a way to address the twin crises of climate change and biodiversity loss, and promote a healthier planet for people and nature.

3.7 The social-economic value of ecosystems will increase in proportion to rising real market incomes and the changing scarcities of ecosystems

3.7.1 Background

Humans derive various benefits from nature, such as through biodiversity, ecosystems or ecosystem functioning. These benefits can manifest as tangible outputs, such as water and food, but also include cultural, recreational, and spiritual interactions that directly or indirectly influence human well-being (e.g., Pascual et al., 2023).

Although assigning monetary values to the benefits humans derived from ecosystem services involves numerous philosophical and practical challenges, as emphasized in the next section, the alternative is often to consider no value at all in governmental planning processes such as benefit-cost analyses, leading to an underinvestment in ecosystems (Dasgupta and Treasury, 2022). Thus, already in 2010, at the 10th Conference of the Parties to the Convention on Biological Diversity in Japan, the international community agreed that the values of biodiversity needed to be integrated into planning processes (Aichi Target 2). In the Kunming-Montreal Global Biodiversity Framework, thisis reflected in Target 14: Integrate Biodiversity in Decision-Making at Every Level.

One quickly realizable way to conceptualize these ecosystem service benefits is through the notion of ecosystem services that include both use and non-use values of nature. The values in this category are anthropocentric, encompassing both instrumental and relational values (IPBES, 2019). The continuous loss of animal and plant species and their respective habitats leads to the loss of the services they provide. To be better able to reflect these ecosystem services in benefit-cost analyses, environmental-economic national accounting or damage litigation processes, governments convert ecosystem services into monetary values (Bishop et al., 2017).

3.7.2 Challenges

Governments around the world are currently looking for new approaches to appropriately assess the benefits from scarce ecosystems and their economic value. This is intended to assist in making the consequences of the destruction or the benefits of the conservation of nature more visible in analyses that underpin political decision-making processes and help with an economically efficient and environmentally effective allocation of tight governmental budgets.

For now, calculation methods of nature's values incorporate—if at all—solely the monetary value of ecosystem services as determined under current conditions (Drupp et al., 2024), which means that nature becomes relatively less valuable over time compared to other goods and services whose value increases with the expected rise in global economic prosperity. In fact also our appreciation of nature increases over time as we get wealthier and ecosystems scarcer. Two factors play a key role in this changing value of scarce ecosystems over time. The prosperity of the world's population is expected to rise—by an estimated inflation-adjusted two percent per year (Müller et al., 2022)—and as household incomes increase, people will be willing to pay more to conserve nature and enjoy its services in the future. In addition, as the services provided by ecosystems become scarcer, this will further increase their value to society. The fact that scarce goods become more expensive is a fundamental principle in economics, and it also applies to nature's values.

3.7.3 Offering solutions

Drupp et al. (2024) provide governments with a ready-to-use formula to estimate the future economic values of scarce ecosystem services that can be used in decision-making processes. The formula scrutinizes up-to-date evidence on the so-called relative price change of non-market environmental goods (e.g., Hoel and Sterner, 2007; Sterner and Persson, 2008; Drupp and Hänsel, 2021) and recommends considering nature's values to increase proportionally with real market income. This is in line with what governmental bodies use to value reductions in mortality risk or travel time. As a result, if only the expected increases in income over the next 100 years were taken into account, the value of global ecosystems would have to increase by more than 130%. This holds for stagnating ecosystems. If ecosystems are projected to decline or degrade further, the value adjustment needs to be higher still. In the case of endangered species, as captured in the prominent Red List Index, for instance, the value adjustment would amount to more than 180%. Accounting for these effects would thus increase the likelihood of projects that conserve ecosystem services to pass a benefit-cost test.

Drupp and Hänsel (2021) apply the formula to the evaluation of global climate policy. Economists typically use integrated climate-economy assessment models, such as the DICE model developed by Nobel Laureate William Nordhaus, to evaluate the trade-offs between mitigation costs and avoided damages from climate change and to estimate the required CO2-prices (Nordhaus, 2019). A key criticism leveled at these models is that they do not appropriately capture the loss of nature's services and thus underestimate climate damages. Drupp and Hänsel (2021) disentangle how non-market goods and services, such as environmental amenities, are captured within these models and explicitly account for this based on an empirical analysis of fundamental drivers of the relative price effect of non-market goods. They find that the social costs of climate change increase by more than 50%, suggesting substantially higher economically optimal CO2-prices (see also section 3.6). The increase in the economically optimal global mean temperature change is accordingly reduced by half a degree Celsius, which highlights the importance of accounting for the scarcity of nature when evaluating climate policy.

3.8 Convivial conservation's principles

3.8.1 Background

Convivial conservation is a new “vision, a politics and a set of governance principles for the future of conservation” (Büscher and Fletcher, 2019, p.284). Through its focus on ‘living with’ biodiversity within planetary boundaries, it aligns with transformative action for climate change (Pörtner et al., 2021b). Grounded in political ecology, it foregrounds the political economy as a significant constraint to transformative conservation. Political ecology is inherently cross-scalar, charting connections from global to local, while emphasising the importance of history and power relations (Watts, 2017). Furthermore, convivial conservation allies itself with social and environmental movements (e.g., Indigenous and decolonial). It proposes a long-term, holistic, “post-capitalist approach to conservation that promotes radical equity, structural transformation, and environmental justice and thus contributes to an overarching movement to create a more equal and sustainable world” (Büscher and Fletcher, 2019, p.283).

3.8.2 Challenges

Convivial conservation responds to two dominant conservation agendas. The first is , ‘new conservation’, which breaks with a long-standing fixation on ‘pristine wilderness’ seen as separate from humans, and instead promotes integration into human development (Sullivan, 2006; Buscher and Fletcher, 2020; Kareiva et al., 2011; Marris, 2013), but do not address the harmful capitalist model of economic development that underpins biodiversity loss (e.g., tourism or payments for ecosystem services). The second approach, neo-protectionism, tries to completely separate nature from human development, calling for an expansion of conventional ’fortress’-style protected areas and therefore reinforces the dichotomies between nature and culture (Hutton et al., 2005; Wuerthner et al., 2015; Buscher and Fletcher, 2020). Although new conservation moves beyond these dualisms, it looks to market mechanisms to fund and save nature (e.g., payments for ecosystem services, ecotourism), creating other social and environmental problems. Convivial conservation proposes that both approaches have limitations, as inherited from thephilosophies and global development models that drive the intertwined biodiversity and climate crises.

3.8.3 Offering solutions

The specific contribution of long-term convivial conservation is that it aims to produce integrated nature-culture spaces within post-capitalist conservation strategies. At its core, it investigates and challenges dominant global political-economic structures, assumptions, beliefs, and knowledge production systems, “including those that are the foundation of paradigms of economic growth and adaptation without limits” (O’Brien and Barnett, 2013, p.385).

Convivial conservation is gaining traction in research, policy and practice (Massarella et al., 2023; Ochieng et al., 2023): “There is widespread agreement that our current reality of global, human-induced ecosystemic and climatic change presents stark challenges for conservation” (Büscher and Fletcher, 2019, p.285). At the same time, breaking through the hegemony of protectionist neoliberal conservation (Fletcher, 2023) is also the greatest challenge for convivial conservation. To further address this challenge, a manifesto was developed that outlines 10 core principles of convivial conservation. We summarise key elements of these principles here; for a complete overview of all 10 principles, we refer to the manifesto website (Centre, 2024).

Humans have always shaped the ecosystems in which they live, co-producing diverse landscapes that in turn shaped and supported people. However, mainstream conservation interventions often separate people from their surrounding ecosystems based on the unfounded assumption that local communities threaten biodiversity (Brockington et al., 2012). The question is not *whether* people should live with the rest of nature, but *how* (see section 3.5).

International and regional inequality contributes to the destruction of global commons necessitating equitable stewardship of ecosystems, centred on those who live within them. Nurturing extra-local commons institutions and economies based on values of care would help cross-generational and cross-scale conviviality. Convivial conservation challenges dominant top-down forms of political power and advocates for inclusive decision-making processes, in particular for those dependent on the ecosystems in question (Lanjouw, 2021). All decisions that can be reached effectively at the local level should be, with higher-level processes that support local autonomy and intervene only when necessary (e.g., Gokkon, 2018, see also section 3.6).

Emphasising only the monetary valuation of biodiversity can be counterproductive. Instruments such as ‘payments for environmental services’, REDD+, and carbon credits use the logic of the problem (capitalist accumulation through the use of natural resources as the logic of the solution (Fletcher, 2023)). This conflicts with convivial co-existence between humans and non-humans, and can undermine other non-monetary ways of valuing nature. It is crucial to support existing livelihoods rather than (further) forcing locals into exploitative external markets. Moreover, mechanisms to redistribute existing wealth and resources would preclude the need to finance conservation through environmentally harmful economic growth (Moranta et al., 2022).

Protected areas have usually relied on paradigms based on positivist scientific knowledge at the expense of rich local and Indigenous philosophies, histories, and practices. However, many different other ways of knowing and practical ways of being in relation to the world such as Ubuntu (Mabele et al., 2022), Buen Vivir, and Eco-Swaraj promote life through mutual care and sharing between humans and non-humans, discouraging individualism and unsustainable extraction (Dickson-Hoyle et al., 2022). This diversity of knowledge must be valued (Orlove et al., 2023).

Too often, those who live in or close to conservation areas are expected to change their behaviour the most (Brockington et al., 2012; Merino and Gustafsson, 2021). However, large industrial extractive practices and high consumption lifestyles drive disproportionate loss of biodiversity. However, these people and organisations are not perceived as causative agents because they are far from conservation spaces or too powerful to influence (Wiedmann et al., 2020). Conservationists should challenge both the regimes that indulge in human rights violations and displacement in the name of biodiversity, and the rights of global or national elites to control or hinder conservation efforts (see also section 3.6).

Some examples where (core elements of) convivial conservation are already visible are the broader investigation of a Conservation Basic Income (CBI) (Fletcher and Büscher 2020; De Lange et al. 2023), early results of which show a promising reduction of logging in the Amazon (Hyolmo, 2025), or human-wildlife cohabitation that is grounded in a strong bottom up approach. A clear example of the latter, focused on human-bear cohabitation in Bulgaria, was investigated by Toncheva et al. (2021).

4 Synthesis

The eight themes introduced above highlight complex interrelationships within the biosphere and their connections to social and economic systems, and as well as to the Earth system. It is evident that various vicious cycles exist. For example, changes in temperature and precipitation patterns as a result of climate change and deforestation can lead to lower agricultural yields and increased fires. This increases pressure on ecosystems and local people, who depend on nature, and face challenges in maintaining their livelihoods and meeting the demand for resources and products in the global market. The provision of various commodities under current trading paradigms and subsidy schemes further fuels climate change, ecosystem degradation and deforestation. In addition to identifying interdependence between these challenges, our eight themes offer four key insights into escape hatches from such cycles.

4.1 1. Improve mechanisms of inclusive decision making

The involvement of diverse stakeholders, including civil society, Indigenous people and local communities and private sector actors, enriches decision-making by incorporating a variety of perspectives and fostering support for innovative solutions (section 3.6). For example, the concept of 'blue justice' advocates for the rights and recognition of small-scale fishers, challenging their marginalisation and empowering them within the regions they inhabit, fostering ecosystem stewardship (section 3.1). Similarly, the integration of indigenous knowledge and governance has proven valuable in improving fire management strategies and promoting biodiversity and fire resilient ecosystems (section 3.3). Such approaches promote equitable and resilient outcomes that align conservation efforts with sustainable development goals (section 3.6). In addition, decision-makers from adjacent ecosystems should sometimes be involved, as, for example, upstream land-based activities have significant impacts on coastal ecosystems (section 3.1).

Raising **public awareness through education** campaigns and **fostering collaboration** enables a holistic approach to environmental challenges (sections 3.1, 3.3. 3.8). Various knowledge systems, such as Ubuntu, Buen Vivir and Eco-Swaraj, emphasise mutual care and sustainable relationships between humans and non-humans. These frameworks discourage individualism and over-exploitation while promoting sustainable living. Incorporating such worldviews into decision-making processes is essential for sustainable and effective governance (section 3.8).

Comprehensive policy packages need to integrate environmental, economic, and social dimensions to address the root causes of environmental degradation and to promote sustainability (sections3.6). These packages should encourage the adoption of cleaner technologies and provide incentives for the conservation and restoration of ecosystems. Initiatives such as the European Green Deal underline the importance of integrating climate and biosphere protection with economic and social objectives. International cooperation is essential to ensure coherent policies across borders and to drive meaningful progress (sections3.6).

4.2 2. Establish and strengthen incentives for sustainable practices

Institutional mechanisms need to be adapted **to support innovative and unconventional practices**, enabling transformative approaches to environmental challenges (section 3.1). Recognising the structural co-benefits of nature-based solutions, such as reducing flood risk and providing additional ecosystem services that come from protectingthe reduction of flood risk and the provision of additional ecosystem services that come from the protection of coastal wetlands, is crucial for integrated policy and planning (section 3.1).

Strengthening financial support, such as tax breaks, subsidies or grants, for actions that adopt sustainable practices can reduce emissions, water use and waste production (section 3.6). For example, strengthening firefighting resources - through increased funding for equipment, personnel and surveillance - improves fire prevention and response capacity. This investment is critical as fire suppression costs are consistently outweighed by the losses from unmanaged fires (section 3.3). Further, future benefits derived from ecosystems should be uplifted proportionally with increasing real market incomes and changing real scarcities of ecosystems (section 3.7).

An exclusive focus on monetary incentives for biodiversity protection undermines its **intrinsic, relational and cultural values**, which are equally important for promoting respect for nature and long-term sustainability (section 3.8). Addressing these dimensions holistically is essential for effective and equitable environmental governance.

4.3 3. Measure and share regional features

Strengthening monitoring capacity is essential for effective environmental management and conservation (section 3.5). For example, increased field measurements in tropical regions are critical to fill gaps in water-related perspectives and to enable country or region-specific analyses to assess the feasibility and cost-benefit trade-offs of different reforestation strategies (section 3.2).

Similarly, fire **risk assessments and forecasts** need to consider regional factors beyond fire weather, including landscape and vegetation characteristics, management practices, ignition sources and socio-economic drivers of vulnerability and exposure (section 3.3).

Environmental certification of imports and exports is essential to maintain high environmental standards. The expansion of existing schemes and the creation of new sector-specific certifications, coupled with regular reviews, transparent reporting and mandatory disclosure of progress, can hold stakeholders accountable to clear benchmarks and timelines (section 3.6). For example, tonne-year accounting provides a scientifically robust method for measuring the climate impact of temporary carbon storage, bringing carbon accounting practices into line with current scientific understanding (section 3.4).

4.4 4. Adopt long lasting holistic landscape management strategies

Humans have always shaped the ecosystems in which they live, co-producing **diverse landscapes** that in turn shaped and supported people (section 3.8). Restoring degraded landscapes worldwide can boost precipitation and mitigate losses from forest degradation (section 3.2). For instance, coastal habitat restoration in Belgium and Hong Kong highlights the co-benefits of nature-based solutions (section 3.1) while national strategies that prioritize biodiversity help to promote fire resilience by avoiding mono-cultures of highly flammable species (section 3.3). Maintaining or restoring 20-25% of (semi-)natural habitat per square kilometre in human-modified landscapes is crucial for maintaining several of nature's contributions to people (NCPs), particularly in agricultural and urban areas. Incorporating habitats such as hedgerows and no-mow zones alongside precision agriculture can balance biodiversity with optimised productivity, making the 25% target a valuable policy tool (section 3.5).

Consider trade-offs carefully: Land fragmentation for fire suppression can reduce species richness, whereas controlled burning may offer a more natural solution, supporting fire-dependent vegetation and biodiversity (section 3.3). Similarly, while afforestation can enhance carbon sequestration and benefit local communities, it requires meticulous planning to avoid unintended ecological consequences (section 3.2). To optimize outcomes, trade-offs and synergies between biodiversity conservation and services like carbon sequestration, coastal protection, water purification, aquaculture, and eco-tourism must be holistically evaluated (section 3.1).

Ecosystem governance should prioritize the people who live within them, empowering Indigenous people and local communities to restore and conserve both livelihoods and biodiversity (section 3.1). Supporting extra-local commons and economies based on values of care contributes to intergenerational and inter-scale sustainability (section 3.8). At the same time, increased transnational cooperation, as exemplified by the Amazon Cooperation Treaty Organization, is essential to combat illegal deforestation and wildlife trafficking and promote more effective conservation strategies (section 3.6).

We note that these four insights align closely. More effective mechanisms of inclusive decision-making are fundamental to promoting the collective effort and will needed to bring transformations of existing structures. Such mechanisms will enable decision-makers to respond to incentives for sustainability and to draw on improved metrics. These, in turn, will support the adoption of long-lasting landscape management strategies.

5 Conclusions

Taken together, these eight themes, described in section 3, illustrate the importance of considering the impact of human activities on surrounding areas when analysing, evaluating or developing policies or economic measures. Focusing exclusively on a single problem, question or objective is not enough. Overly siloed approaches can overlook or even exacerbate, existing problems in other areas (Fanning et al., 2022). As different aspects of the Earth system crisis are typically addressed by different research disciplines, closer collaboration between scientists of diverse fields is essential to develop a holistic understanding and effectively tackle complex and critical issues even in smaller research projects. This interdisciplinary approach is already practiced in the major reports such as those by IPBES and IPCC.

Our interdisciplinary study is another example of an effective, collaborative methodology that brings together experts from different disciplines and regions, and illustrates the great value of interdisciplinary collaboration in advancing science and supporting decision-makers. Nevertheless, this collection of pressing ecological issues does not claim to be exhaustive, and the compilation may be superficial on some topics that require more in-depth discussion. However, it could serve as the first in a series of annual synthesis reports that provide actionable insights and bridge the information gap between the major

IPCC and IPBES assessments, while complementing studies such as the "10 New Insights in Climate Science" or "Scientists' Warning" series. In these future reports, we need to encourage greater contributions from scientists in other regions of the world, particularly the Global South, to incorporate their knowledge and perspectives. Their insights can help identify new targets and research questions that may have been overlooked so far.

Despite receiving less public attention than other currently dominant issues, the Earth System crisis - including climate change, biodiversity loss, pollution and land-use change - remains the major challenge of this century. While many ecosystems around the world are suffering from these threats, healthy ecosystems also offer significant potential to mitigate or adapt to many aspects of Earth system crises. Addressing these interlinked challenges for ecosystems, including the socio-economic dimensions, requires interdisciplinary and integrative approaches to develop effective and sustainable solutions.

In conclusion, we curated this list of pressing environmental issues and recommendations to underscore that we are not limited by how much we know about the problem or how much we know about how to act. The obstacles are structural, cultural and political in nature. They prevent the necessary pace and scale of implementation needed to achieve various international commitments and the goals of the Paris Agreement and the Kunming-Montreal Global Biodiversity Framework in a fair and equitable manner. Effective implementation of these eight themes helpt to can promote a flourishing biosphere that facilitates economic, cultural, and spiritual interactions essential to human well-being

Author contributions. Conceiving and designing the study and providing editorial oversight: FJB, NK, AB, AR, RM, GBS. Constituted the Editorial Board to select the themes: AB, LP, GH, CK, AR, AG. Led and coordinated the overall writing: FJB. Lead-authors of writing teams: FJB, GBS, AR, JH, DM, AG, AM, SK, MH, RM. Performed literature review: all. Contributed to the writing: all.

Competing interests. one of the co-authors is a member of the editorial board of BG (Anja Rammig)

References

2024, W.: State of the Global Climate 2023, Tech. Rep. WMO-No. 1347, World Meteorological Organization (WMO), Geneva, 2024.

Abatzoglou, J. T., Williams, A. P., and Barbero, R.: Global Emergence of Anthropogenic Climate Change in Fire Weather Indices, Geophysical Research Letters, 46, 326–336, https://doi.org/10.1029/2018GL080959, 2019.

Allan, J. R., Possingham, H. P., Atkinson, S. C., Waldron, A., Di Marco, M., Butchart, S. H., Adams, V. M., Kissling, W. D., Worsdell, T., Sandbrook, C., and others: The minimum land area requiring conservation attention to safeguard biodiversity, Science, 376, 1094–1101, https://doi.org/DOI: 10.1126/science.abl9127, 2022.

Alongi, D. M.: Carbon sequestration in mangrove forests, Carbon management, 3, 313–322, https://doi.org/10.4155/cmt.12.20, 2012.

Andela, N., Morton, D. C., Giglio, L., Chen, Y., van der Werf, G. R., Kasibhatla, P. S., DeFries, R. S., Collatz, G., Hantson, S., Kloster, S., and others: A human-driven decline in global burned area, Science, 356, 1356–1362, https://doi.org/https://doi.org/10.1126/science.aal4108, 2017.

Andela, N., Morton, D. C., Schroeder, W., Chen, Y., Brando, P. M., and Randerson, J. T.: Tracking and classifying Amazon fire events in near real time, Science Advances, 8, 1356–1362, https://doi.org/10.1126/sciadv.abd2713, 2022.

Anderegg, W. R. L., Trugman, A. T., Badgley, G., Anderson, C. M., Bartuska, A., Ciais, P., Cullenward, D., Field, C. B., Freeman, J., Goetz, S. J., Hicke, J. A., Huntzinger, D., Jackson, R. B., Nickerson, J., Pacala, S., and Randerson, J. T.: Climate-driven risks to the climate mitigation potential of forests, Science, 368, eaaz7005, https://doi.org/10.1126/science.aaz7005, 2020.

Apine, E. and Stojanovic, T.: Is the coastal future green, grey or hybrid? Diverse perspectives on coastal flood risk management and adaptation in the UK, Cambridge Prisms: Coastal Futures, 2, e4, https://doi.org/10.1017/cft.2024.4, 2024.

Arroyo-Rodríguez, V., Fahrig, L., Tabarelli, M., Watling, J. I., Tischendorf, L., Benchimol, M., Cazetta, E., Faria, D., Leal, I. R., Melo, F. P. L., Morante-Filho, J. C., Santos, B. A., Arasa-Gisbert, R., Arce-Peña, N., Cervantes-López, M. J., Cudney-Valenzuela, S., Galán-Acedo, C., San-José, M., Vieira, I. C. G., Slik, J. F., Nowakowski, A. J., and Tscharntke, T.: Designing optimal human-modified landscapes for forest biodiversity conservation, Ecology Letters, 23, 1404–1420, https://doi.org/10.1111/ele.13535, 2020.

Ascoli, D., Plana, E., Oggioni, S. D., Tomao, A., Colonico, M., Corona, P., Giannino, F., Moreno, M., Xanthopoulos, G., Kaoukis, K., Athanasiou, M., Colaço, M. C., Rego, F., Sequeira, A. C., Acácio, V., Serra, M., and Barbati, A.: Fire-smart solutions for sustainable wildfire risk prevention: Bottom-up initiatives meet top-down policies under EU green deal, International Journal of Disaster Risk Reduction, 92, 103 715, https://doi.org/10.1016/j.ijdrr.2023.103715, 2023.

Atanasov, A. G., Zotchev, S. B., Dirsch, V. M., and Supuran, C. T.: Natural products in drug discovery: advances and opportunities, Nature reviews Drug discovery, 20, 200–216, publisher: Nature Publishing Group, 2021.

Ayugi, B., Eresanya, E. O., Onyango, A. O., Ogou, F. K., Okoro, E. C., Okoye, C. O., Anoruo, C. M., Dike, V. N., Ashiru, O. R., Daramola, M. T., and others: Review of meteorological drought in Africa: historical trends, impacts, mitigation measures, and prospects, Pure and Applied Geophysics, 179, 1365–1386, publisher: Springer, 2022.

Baker, J. C. A. and Spracklen, D. V.: Divergent Representation of Precipitation Recycling in the Amazon and the Congo in CMIP6 Models, Geophysical Research Letters, 49, e2021GL095 136, https://doi.org/10.1029/2021GL095136, 2022.

Balafoutis, A., Beck, B., Fountas, S., Vangeyte, J., Wal, T. V. d., Soto, I., Gómez-Barbero, M., Barnes, A., and Eory, V.: Precision Agriculture Technologies Positively Contributing to GHG Emissions Mitigation, Farm Productivity and Economics, Sustainability, 9, 1339, https://doi.org/10.3390/su9081339, 2017.

Barlow, J., França, F., Gardner, T. A., Hicks, C. C., Lennox, G. D., Berenguer, E., Castello, L., Economo, E. P., Ferreira, J., Guénard, B., Gontijo Leal, C., Isaac, V., Lees, A. C., Parr, C. L., Wilson, S. K., Young, P. J., and Graham, N. A. J.: The future of hyperdiverse tropical ecosystems, Nature, 559, 517–526, https://doi.org/10.1038/s41586-018-0301-1, 2018.

Bastos Lima, M. G. and Persson, U. M.: Commodity-Centric Landscape Governance as a Double-Edged Sword: The Case of Soy and the Cerrado Working Group in Brazil, Frontiers in Forests and Global Change, 3, https://doi.org/10.3389/ffgc.2020.00027, 2020.

Bayham, J., Yoder, J. K., Champ, P. A., and Calkin, D. E.: The Economics of Wildfire in the United States, Annual Review of Resource Economics, 14, 379–401, https://doi.org/10.1146/annurev-resource-111920-014804, 2022.

Bedia, J., Herrera, S., Gutiérrez, J. M., Benali, A., Brands, S., Mota, B., and Moreno, J. M.: Global patterns in the sensitivity of burned area to fire-weather: Implications for climate change, Agricultural and Forest Meteorology, 214-215, 369–379, https://doi.org/10.1016/j.agrformet.2015.09.002, 2015.

Beetz, K., Marrs, C., Busse, A., Poděbradská, M., Kinalczyk, D., Kranz, J., and Forkel, M.: Effects of bark beetle disturbance and fuel types on fire radiative power and burn severity in the Bohemian-Saxon Switzerland, Forestry: An International Journal of Forest Research, p. cpae024, https://doi.org/10.1093/forestry/cpae024, 2024.

Bishop, R. C., Boyle, K. J., Carson, R. T., Chapman, D., Hanemann, W. M., Kanninen, B., Kopp, R. J., Krosnick, J. A., List, J., Meade, N., and others: Putting a value on injuries to natural assets: The BP oil spill, Science, 356, 253–254, https://doi.org/10.1126/science.aam8124, 2017.

Blanco-Canqui, H., Shaver, T. M., Lindquist, J. L., Shapiro, C. A., Elmore, R. W., Francis, C. A., and Hergert, G. W.: Cover Crops and Ecosystem Services: Insights from Studies in Temperate Soils, Agronomy Journal, 107, 2449–2474, https://doi.org/10.2134/agronj15.0086, 2015.

Bloem, S., Cullen, A. C., Mearns, L. O., and Abatzoglou, J. T.: The Role of International Resource Sharing Arrangements in Managing Fire in the Face of Climate Change, Fire, 5, 88, https://doi.org/10.3390/fire5040088, 2022.

Blythe, J. L., Gill, D. A., Claudet, J., Bennett, N. J., Gurney, G. G., Baggio, J. A., Ban, N. C., Bernard, M. L., Brun, V., Darling, E. S., Franco, A. D., Epstein, G., Franks, P., Horan, R., Jupiter, S. D., Lau, J., Lazzari, N., Mahajan, S. L., Mangubhai, S., Naggea, J., Turner, R. A., and Zafra-Calvo, N.: Blue justice: A review of emerging scholarship and resistance movements, Cambridge Prisms: Coastal Futures, 1, e15, https://doi.org/10.1017/cft.2023.4, 2023.

Bochow, N. and Boers, N.: The South American monsoon approaches a critical transition in response to deforestation, Science Advances, 9, eadd9973, https://doi.org/10.1126/sciadv.add9973, 2023.

Bocken, N., Strupeit, L., Whalen, K., and Nußholz, J.: A Review and Evaluation of Circular Business Model Innovation Tools, Sustainability, 11, 2210, https://doi.org/10.3390/su11082210, 2019.

Bonan, G. B.: Forests and climate change: forcings, feedbacks, and the climate benefits of forests, science, 320, 1444–1449, https://doi.org/10.1126/science.1155121, 2008.

Bond, W. J. and Keeley, J. E.: Fire as a global 'herbivore': the ecology and evolution of flammable ecosystems, Trends in Ecology & Evolution, 20, 387–394, https://doi.org/10.1016/j.tree.2005.04.025, 2005.

Bourgoin, C., Ceccherini, G., Girardello, M., Vancutsem, C., Avitabile, V., Beck, P. S. A., Beuchle, R., Blanc, L., Duveiller, G., Migliavacca, M., Vieilledent, G., Cescatti, A., and Achard, F.: Human degradation of tropical moist forests is greater than previously estimated, Nature, 631, 570–576, https://doi.org/10.1038/s41586-024-07629-0, publisher: Nature Publishing Group, 2024.

Bowman, D. M. J. S., Balch, J., Artaxo, P., Bond, W. J., Cochrane, M. A., D'Antonio, C. M., DeFries, R., Johnston, F. H., Keeley, J. E., Krawchuk, M. A., Kull, C. A., Mack, M., Moritz, M. A., Pyne, S., Roos, C. I., Scott, A. C., Sodhi, N. S., and Swetnam, T. W.: The human dimension of fire regimes on Earth, Journal of Biogeography, 38, 2223–2236, https://doi.org/10.1111/j.1365-2699.2011.02595.x, 2011.

Brancalion, P. H. S., de Almeida, D. R. A., Vidal, E., Molin, P. G., Sontag, V. E., Souza, S. E. X. F., and Schulze, M. D.: Fake legal logging in the Brazilian Amazon, Science Advances, 4, eaat1192, https://doi.org/10.1126/sciadv.aat1192, 2018.

Brander, M. and Broekhoff, D.: Methods that equate temporary carbon storage with permanent CO2 emission reductions lead to false claims on temperature alignment, Carbon Management, 14, 2284 714, https://doi.org/10.1080/17583004.2023.2284714, 2023.

Brockington, D., Duffy, R., and Igoe, J.: Nature unbound: conservation, capitalism and the future of protected areas, Routledge, https://doi.org/10.4324/9781849772075, 2012.

Brown, P. T., Hanley, H., Mahesh, A., Reed, C., Strenfel, S. J., Davis, S. J., Kochanski, A. K., and Clements, C. B.: Climate warming increases extreme daily wildfire growth risk in California, Nature, 621, 760–766, https://doi.org/10.1038/s41586-023-06444-3, 2023.

Bruijnzeel, L., Mulligan, M., and Scatena, F. N.: Hydrometeorology of tropical montane cloud forests: emerging patterns, Hydrological Processes, 25, 465–498, publisher: Wiley Online Library, 2011.

Burton, C., Lampe, S., Kelley, D. I., Thiery, W., Hantson, S., Christidis, N., Gudmundsson, L., Forrest, M., Burke, E., Chang, J., Huang, H., Ito, A., Kou-Giesbrecht, S., Lasslop, G., Li, W., Nieradzik, L., Li, F., Chen, Y., Randerson, J., Reyer, C. P. O., and Mengel, M.: Global burned area increasingly explained by climate change, Nature Climate Change, 14, 1186–1192, https://doi.org/10.1038/s41558-024-02140-w, 2024.

Buscher, B. and Fletcher, R.: The conservation revolution: radical ideas for saving nature beyond the Anthropocene, Verso Books, 2020.

Bustamante, M., Roy, J., Ospina, D., Achakulwisut, P., Aggarwal, A., Bastos, A., Broadgate, W., Canadell, J. G., Carr, E. R., Chen, D., and others: Ten new insights in climate science 2023, Global Sustainability, 7, e19, https://doi.org/10.1017/sus.2023.25, 2023.

Büscher, B. and Fletcher, R.: Towards Convivial Conservation, Conservation and Society, 17, 283, https://doi.org/10.4103/cs.cs_19_75, 2019.

Caporaso, L., Duveiller, G., Giuliani, G., Giorgi, F., Stengel, M., Massaro, E., Piccardo, M., and Cescatti, A.: Converging Findings of Climate Models and Satellite Observations on the Positive Impact of European Forests on Cloud Cover, Journal of Geophysical Research: Atmospheres, 129, e2023JD039 235, https://doi.org/10.1029/2023JD039235, _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1029/2023JD039235, 2024.

Cariveau, D. P., Bruninga-Socolar, B., and Pardee, G. L.: A review of the challenges and opportunities for restoring animal-mediated pollination of native plants, Emerging Topics in Life Sciences, 4, 99–109, https://doi.org/10.1042/ETLS20190073, 2020.

Carton, W., Lund, J. F., and Dooley, K.: Undoing Equivalence: Rethinking Carbon Accounting for Just Carbon Removal, Frontiers in Climate, 3, https://doi.org/10.3389/fclim.2021.664130, 2021.

Carton, W., Hougaard, I.-M., Markusson, N., and Lund, J. F.: Is carbon removal delaying emission reductions?, WIREs Climate Change, 14, e826, https://doi.org/10.1002/wcc.826, 2023.

Cavicchioli, R., Ripple, W. J., Timmis, K. N., Azam, F., Bakken, L. R., Baylis, M., Behrenfeld, M. J., Boetius, A., Boyd, P. W., Classen, A. T., Crowther, T. W., Danovaro, R., Foreman, C. M., Huisman, J., Hutchins, D. A., Jansson, J. K., Karl, D. M., Koskella, B., Mark Welch, D. B., Martiny, J. B. H., Moran, M. A., Orphan, V. J., Reay, D. S., Remais, J. V., Rich, V. I., Singh, B. K., Stein, L. Y., Stewart, F. J., Sullivan, M. B., van Oppen, M. J. H., Weaver, S. C., Webb, E. A., and Webster, N. S.: Scientists' warning to humanity: microorganisms and climate change, Nature Reviews Microbiology, 17, 569–586, https://doi.org/10.1038/s41579-019-0222-5, 2019.

Centre, C. C.: Convivial Conservation Manifesto, https://www.convivialconservation.com/2024/05/14/convivial-conservation-manifesto-is-available-online-now/, 2024.

Chazdon, R. L., Lindenmayer, D., Guariguata, M. R., Crouzeilles, R., Benayas, J. M. R., and Chavero, E. L.: Fostering natural forest regeneration on former agricultural land through economic and policy interventions, Environmental Research Letters, 15, 043 002, https://doi.org/10.1088/1748-9326/ab79e6, 2020.

Chen, Y., Hall, J., van Wees, D., Andela, N., Hantson, S., Giglio, L., van der Werf, G. R., Morton, D. C., and Randerson, J. T.: Multi-decadal trends and variability in burned area from the fifth version of the Global Fire Emissions Database (GFED5), Earth System Science Data, 15, 5227–5259, https://doi.org/10.5194/essd-15-5227-2023, 2023.

Cheung, S. C.: The politics of wetlandscape: fishery heritage and natural conservation in Hong Kong, International Journal of Heritage Studies, 17, 36–45, https://doi.org/10.1080/13527258.2011.524004, 2011.

Chuvieco, E., Pettinari, M. L., Koutsias, N., Forkel, M., Hantson, S., and Turco, M.: Human and climate drivers of global biomass burning variability, Science of The Total Environment, 779, 146 361, https://doi.org/10.1016/j.scitotenv.2021.146361, 2021.

Chuvieco, E., Yebra, M., Martino, S., Thonicke, K., Gómez-Giménez, M., San-Miguel, J., Oom, D., Velea, R., Mouillot, F., Molina, J. R., Miranda, A. I., Lopes, D., Salis, M., Bugaric, M., Sofiev, M., Kadantsev, E., Gitas, I. Z., Stavrakoudis, D., Eftychidis, G., Bar-Massada, A., Neidermeier, A., Pampanoni, V., Pettinari, M. L., Arrogante-Funes, F., Ochoa, C., Moreira, B., and Viegas, D.: Towards an Integrated Approach to Wildfire Risk Assessment: When, Where, What and How May the Landscapes Burn, Fire, 6, 215, https://doi.org/10.3390/fire6050215, 2023.

Clarke, H., Nolan, R. H., De Dios, V. R., Bradstock, R., Griebel, A., Khanal, S., and Boer, M. M.: Forest fire threatens global carbon sinks and population centres under rising atmospheric water demand, Nature Communications, 13, 7161, https://doi.org/10.1038/s41467-022-34966-3, 2022.

Climate Focus: Off track and falling behind: Tracking progress on 2030 forest goals, Tech. rep., www.forestdeclaration.org., 2023.

Collins, L., Bradstock, R. A., Clarke, H., Clarke, M. F., Nolan, R. H., and Penman, T. D.: The 2019/2020 mega-fires exposed Australian ecosystems to an unprecedented extent of high-severity fire, Environmental Research Letters, 16, 044 029, https://doi.org/10.1088/1748-9326/abeb9e, 2021.

Commar, L. F. S., Abrahão, G. M., and Costa, M. H.: A possible deforestation-induced synoptic-scale circulation that delays the rainy season onset in Amazonia, Environmental Research Letters, 18, 044 041, https://doi.org/10.1088/1748-9326/acc95f, 2023.

Commission, E.: Factsheets on the European Green Deal - European Commission, https://commission.europa.eu/publications/factsheets-european-green-deal_en, 2019.

Connor, T., Tripp, E., Tripp, B., Saxon, B., Camarena, J., Donahue, A., Sarna-Wojcicki, D., Macaulay, L., Bean, T., Hanbury-Brown, A., and others: Karuk ecological fire management practices promote elk habitat in northern California, Journal of Applied Ecology, 59, 1874–1883, https://doi.org/10.1111/1365-2664.14194, 2022.

Copernicus: Canada produced 23% of the global wildfire carbon emissions for 2023, https://atmosphere.copernicus.eu/copernicus-canada-produced-23-global-wildfire-carbon-emissions-2023#, 2023.

Costanza, R., de Groot, R., Sutton, P., van der Ploeg, S., Anderson, S. J., Kubiszewski, I., Farber, S., and Turner, R. K.: Changes in the global value of ecosystem services, Global Environmental Change, 26, 152–158, https://doi.org/10.1016/j.gloenvcha.2014.04.002, 2014.

Cowie, R. H., Bouchet, P., and Fontaine, B.: The Sixth Mass Extinction: fact, fiction or speculation?, Biological Reviews, 97, 640–663, https://doi.org/10.1111/brv.12816, 2022.

Croker, A. R., Woods, J., and Kountouris, Y.: Changing fire regimes in East and Southern Africa's savanna-protected areas: opportunities and challenges for indigenous-led savanna burning emissions abatement schemes, Fire Ecology, 19, 63, https://doi.org/10.1186/s42408-023-00215-1, 2023.

Crutzen, P. J.: The "anthropocene", in: Earth system science in the anthropocene, pp. 13–18, Springer, Berlin, Heidelberg: Springer Berlin Heidelberg., 2006.

Cunningham, C. X., Williamson, G. J., and Bowman, D. M. J. S.: Increasing frequency and intensity of the most extreme wildfires on Earth, Nature Ecology & Evolution, pp. 1–6, https://doi.org/10.1038/s41559-024-02452-2, 2024.

Dasgupta, P. and Treasury, H.: The economics of biodiversity: the Dasgupta review, Odisha Economic Journal, 54, 170–176, 2022.

Dawson, N. M., Coolsaet, B., Bhardwaj, A., Booker, F., Brown, D., Lliso, B., Loos, J., Martin, A., Oliva, M., Pascual, U., Sherpa, P., and Worsdell, T.: Is it just conservation? A typology of Indigenous peoples' and local communities' roles in conserving biodiversity, One Earth, 7, 1007–1021, https://doi.org/10.1016/j.oneear.2024.05.001, 2024.

Dean, A. J., Uebel, K., Schultz, T., Fielding, K. S., Saeck, E., Ross, H., and Martin, V.: Community stewardship to protect coastal and freshwater ecosystems–pathways between recreation and stewardship intentions, People and Nature, 6, 1452–1468, https://doi.org/10.1002/pan3.10658, 2024.

Dickson-Hoyle, S., Ignace, R. E., Ignace, M. B., Hagerman, S. M., Daniels, L. D., and Copes-Gerbitz, K.: Walking on two legs: a pathway of Indigenous restoration and reconciliation in fire-adapted landscapes, Restoration Ecology, 30, e13 566, https://doi.org/10.1111/rec.13566, 2022.

Dodge, M.: Forest Fuel Accumulation—A Growing Problem, Science, 177, 139–142, https://doi.org/10.1126/science.177.4044.139, 1972.

Doelman, J. C., Stehfest, E., van Vuuren, D. P., Tabeau, A., Hof, A. F., Braakhekke, M. C., Gernaat, D. E. H. J., van den Berg, M., van Zeist, W.-J., Daioglou, V., van Meijl, H., and Lucas, P. L.: Afforestation for climate change mitigation: Potentials, risks and trade-offs, Global Change Biology, 26, 1576–1591, https://doi.org/10.1111/gcb.14887, 2020.

Drupp, M., Hänsel, M., Fenichel, E., Freeman, M., Gollier, C., Groom, B., Heal, G., Howard, P., Millner, A., Moore, F., and others: Accounting for the increasing benefits from scarce ecosystems, Science, 383, 1062–1064, https://doi.org/10.1126/science.adk2086, 2024.

Drupp, M. A. and Hänsel, M. C.: Relative prices and climate policy: how the scarcity of nonmarket goods drives policy evaluation, American Economic Journal: Economic Policy, 13, 168–201, 2021.

Díaz, S., Pascual, U., Stenseke, M., Martín-López, B., Watson, R. T., Molnár, Z., Hill, R., Chan, K. M., Baste, I. A., Brauman, K. A., and others: Assessing nature's contributions to people, Science, 359, 270–272, https://doi.org/10.1126/science.aap8826, 2018.

Díaz, S., Zafra-Calvo, N., Purvis, A., Verburg, P. H., Obura, D., Leadley, P., Chaplin-Kramer, R., De Meester, L., Dulloo, E., Martín-López, B., and others: Set ambitious goals for biodiversity and sustainability, Science, 370, 411–413, https://doi.org/10.1126/science.abe1530, 2020.

EEA: Mapping the impacts of natural hazards and technological accidents in Europe – An overview of the last decade., EEA Technical Report 13/2010, European Environment Agency, Copenhagen, Denmark, doi:10.2800/62638, 2010.

Eeraerts, M.: A minimum of 15% semi-natural habitat facilitates adequate wild pollinator visitation to a pollinator-dependent crop, Biological Conservation, 278, 109 887, https://doi.org/10.1016/j.biocon.2022.109887, 2023.

Ellison, D., Morris, C. E., Locatelli, B., Sheil, D., Cohen, J., Murdiyarso, D., Gutierrez, V., Noordwijk, M. v., Creed, I. F., Pokorny, J., Gaveau, D., Spracklen, D. V., Tobella, A. B., Ilstedt, U., Teuling, A. J., Gebrehiwot, S. G., Sands, D. C., Muys, B., Verbist, B., Springgay, E., Sugandi, Y., and Sullivan, C. A.: Trees, forests and water: Cool insights for a hot world, Global Environmental Change, 43, 51–61, https://doi.org/10.1016/j.gloenvcha.2017.01.002, 2017.

European Environment Agency: European climate risk assessment: executive summary, Publications Office of the European Union, https://data.europa.eu/doi/10.2800/204249, 2024.

Ewert, F., Baatz, R., and Finger, R.: Agroecology for a Sustainable Agriculture and Food System: From Local Solutions to Large-Scale Adoption, Annual Review of Resource Economics, 15, 351–381, https://doi.org/10.1146/annurev-resource-102422-090105, 2023.

Fa, J. E., Watson, J. E., Leiper, I., Potapov, P., Evans, T. D., Burgess, N. D., Molnár, Z., Fernández-Llamazares, A., Duncan, T., Wang, S., Austin, B. J., Jonas, H., Robinson, C. J., Malmer, P., Zander, K. K., Jackson, M. V., Ellis, E., Brondizio, E. S., and Garnett, S. T.: Importance of Indigenous Peoples' lands for the conservation of Intact Forest Landscapes, Frontiers in Ecology and the Environment, 18, 135–140, https://doi.org/10.1002/fee.2148, 2020.

Fahad, S., Chavan, S. B., Chichaghare, A. R., Uthappa, A. R., Kumar, M., Kakade, V., Pradhan, A., Jinger, D., Rawale, G., Yadav, D. K., Kumar, V., Farooq, T. H., Ali, B., Sawant, A. V., Saud, S., Chen, S., and Poczai, P.: Agroforestry Systems for Soil Health Improvement and Maintenance, Sustainability, 14, 14 877, https://doi.org/10.3390/su142214877, 2022.

Fanning, A. L., O'Neill, D. W., Hickel, J., and Roux, N.: The social shortfall and ecological overshoot of nations, Nature Sustainability, 5, 26–36, https://doi.org/10.1038/s41893-021-00799-z, 2022.

FAO: The state of the world's forests 2022. Forest pathways for green recovery and building inclusive, resilient and sustainable economies, Tech. rep., FAO, 2022a.

FAO: The State of Agricultural Commodity Markets 2022. The geography of food and agricultural trade:Policy approaches for sustainable development., Tech. rep., FAO, https://doi.org/10.4060/cc0471en, rome, FAO., 2022b.

FAO: World Food and Agriculture: Statistical Yearbook 2023, Tech. rep., FAO, Rome, https://doi.org/10.4060/cc8166en-fig03, 2023.

Farley, K. A., Jobbágy, E. G., and Jackson, R. B.: Effects of afforestation on water yield: a global synthesis with implications for policy, Global change biology, 11, 1565–1576, https://doi.org/10.1111/j.1365-2486.2005.01011.x, 2005.

Feng, X., Porporato, A., and Rodriguez-Iturbe, I.: Changes in rainfall seasonality in the tropics, Nature Climate Change, 3, 811–815, https://doi.org/10.1038/nclimate1907, 2013.

Feng, Y., Zeng, Z., Searchinger, T. D., Ziegler, A. D., Wu, J., Wang, D., He, X., Elsen, P. R., Ciais, P., Xu, R., Guo, Z., Peng, L., Tao, Y., Spracklen, D. V., Holden, J., Liu, X., Zheng, Y., Xu, P., Chen, J., Jiang, X., Song, X.-P., Lakshmi, V., Wood, E. F., and Zheng, C.: Doubling of annual forest carbon loss over the tropics during the early twenty-first century, Nature Sustainability, 5, 444–451, https://doi.org/10.1038/s41893-022-00854-3, 2022.

Fernandes, G. W., Coelho, M. S., Machado, R. B., Ferreira, M. E., Aguiar, L. M. d. S., Dirzo, R., Scariot, A., and Lopes, C. R.: Afforestation of savannas: an impending ecological disaster, Natureza & Conservação, 14, 146–151, https://doi.org/https://doi.org/10.1016/j.ncon.2016.08.002, 2016.

Fernandes, S., Athayde, S., Harrison, I., and Perry, D.: Connectivity and policy confluences: a multi-scalar conservation approach for protecting Amazon riverine ecosystems, Perspectives in Ecology and Conservation, 22, 129–136, https://doi.org/10.1016/j.pecon.2024.02.002, 2024.

Fletcher, R.: Failing forward: The rise and fall of neoliberal conservation, Univ of California Press, 2023.

Folke, C., Polasky, S., Rockström, J., Galaz, V., Westley, F., Lamont, M., Scheffer, M., Österblom, H., Carpenter, S. R., Chapin, F. S., Seto, K. C., Weber, E. U., Crona, B. I., Daily, G. C., Dasgupta, P., Gaffney, O., Gordon, L. J., Hoff, H., Levin, S. A., Lubchenco, J., Steffen, W., and Walker, B. H.: Our future in the Anthropocene biosphere, Ambio, 50, 834–869, https://doi.org/10.1007/s13280-021-01544-8, 2021.

Forrest, M., Hetzer, J., Billing, M., Bowring, S. P. K., Kosczor, E., Oberhagemann, L., Perkins, O., Warren, D., Arrogante-Funes, F., Thonicke, K., and Hickler, T.: Understanding and simulating cropland and non-cropland burning in Europe using the BASE (Burnt Area Simulator for Europe) model, Biogeosciences, 21, 5539–5560, https://doi.org/10.5194/bg-21-5539-2024, 2024.

Forzieri, G., Bianchi, A., Silva, F. B. e., Marin Herrera, M. A., Leblois, A., Lavalle, C., Aerts, J. C. J. H., and Feyen, L.: Escalating impacts of climate extremes on critical infrastructures in Europe, Global Environmental Change, 48, 97–107, https://doi.org/10.1016/j.gloenvcha.2017.11.007, 2018.

Forzieri, G., Miralles, D. G., Ciais, P., Alkama, R., Ryu, Y., Duveiller, G., Zhang, K., Robertson, E., Kautz, M., Martens, B., Jiang, C., Arneth, A., Georgievski, G., Li, W., Ceccherini, G., Anthoni, P., Lawrence, P., Wiltshire, A., Pongratz, J., Piao, S., Sitch, S., Goll, D. S., Arora, V. K., Lienert, S., Lombardozzi, D., Kato, E., Nabel, J. E. M. S., Tian, H., Friedlingstein, P., and Cescatti, A.: Increased control of vegetation on global terrestrial energy fluxes, Nature Climate Change, 10, 356–362, https://doi.org/10.1038/s41558-020-0717-0, 2020.

Fox, N., Tilt, J. H., Ruggiero, P., Stanton, K., and Bolte, J.: Toward equitable coastal community resilience: Incorporating principles of equity and justice in coastal hazard adaptation, Cambridge Prisms: Coastal Futures, 1, e36, https://doi.org/10.1017/cft.2023.24, 2023.

Friedlingstein, P., O'Sullivan, M., Jones, M. W., Andrew, R. M., Bakker, D. C. E., Hauck, J., Landschützer, P., Le Quéré, C., Luijkx, I. T., Peters, G. P., Peters, W., Pongratz, J., Schwingshackl, C., Sitch, S., Canadell, J. G., Ciais, P., Jackson, R. B., Alin, S. R., Anthoni, P., Barbero, L., Bates, N. R., Becker, M., Bellouin, N., Decharme, B., Bopp, L., Brasika, I. B. M., Cadule, P., Chamberlain, M. A., Chandra, N., Chau, T.-T.-T., Chevallier, F., Chini, L. P., Cronin, M., Dou, X., Enyo, K., Evans, W., Falk, S., Feely, R. A., Feng, L., Ford, D. J., Gasser, T., Ghattas, J., Gkritzalis, T., Grassi, G., Gregor, L., Gruber, N., Gürses, O., Harris, I., Hefner, M., Heinke, J., Houghton, R. A., Hurtt, G. C., Iida, Y., Ilyina, T., Jacobson, A. R., Jain, A., Jarníková, T., Jersild, A., Jiang, F., Jin, Z., Joos, F., Kato, E., Keeling, R. F., Kennedy, D., Klein Goldewijk, K., Knauer, J., Korsbakken, J. I., Körtzinger, A., Lan, X., Lefèvre, N., Li, H., Liu, J., Liu, Z., Ma, L., Marland, G., Mayot, N., McGuire, P. C., McKinley, G. A., Meyer, G., Morgan, E. J., Munro, D. R., Nakaoka, S.-I., Niwa, Y., O'Brien, K. M., Olsen, A., Omar, A. M., Ono, T., Paulsen, M., Pierrot, D., Pocock, K., Poulter, B., Powis, C. M., Rehder, G., Resplandy, L., Robertson, E., Rödenbeck, C., Rosan, T. M., Schwinger, J., Séférian, R., Smallman, T. L., Smith, S. M., Sospedra-Alfonso, R., Sun, Q., Sutton, A. J., Sweeney, C., Takao, S., Tans, P. P., Tian, H., Tilbrook, B., Tsujino, H., Tubiello, F., van der Werf, G. R., van Ooijen, E., Wanninkhof, R., Watanabe, M., Wimart-Rousseau, C., Yang, D., Yang, X., Yuan, W., Yue, X., Zaehle, S., Zeng, J., and Zheng, B.: Global Carbon Budget 2023, Earth System Science Data, 15, 5301–5369, https://doi.org/10.5194/essd-15-5301-2023, 2023.

Fu, R.: Global warming-accelerated drying in the tropics, Proceedings of the National Academy of Sciences, 112, 3593–3594, https://doi.org/10.1073/pnas.1503231112, 2015.

Fu, R., Yin, L., Li, W., Arias, P. A., Dickinson, R. E., Huang, L., Chakraborty, S., Fernandes, K., Liebmann, B., Fisher, R., and Myneni, R. B.: Increased dry-season length over southern Amazonia in recent decades and its implication for future climate projection, Proceedings of the National Academy of Sciences, 110, 18 110–18 115, https://doi.org/10.1073/pnas.1302584110, 2013.

Fuhrman, J., Bergero, C., Weber, M., Monteith, S., Wang, F. M., Clarens, A. F., Doney, S. C., Shobe, W., and McJeon, H.: Diverse carbon dioxide removal approaches could reduce impacts on the energy–water–land system, Nature Climate Change, 13, 341–350, https://doi.org/10.1038/s41558-023-01604-9, 2023.

Garibaldi, L. A., Steffan-Dewenter, I., Kremen, C., Morales, J. M., Bommarco, R., Cunningham, S. A., Carvalheiro, L. G., Chacoff, N. P., Dudenhöffer, J. H., Greenleaf, S. S., Holzschuh, A., Isaacs, R., Krewenka, K., Mandelik, Y., Mayfield, M. M., Morandin, L. A., Potts, S. G., Ricketts, T. H., Szentgyörgyi, H., Viana, B. F., Westphal, C., Winfree, R., and Klein, A. M.: Stability of pollination services decreases with isolation from natural areas despite honey bee visits, Ecology Letters, 14, 1062–1072, https://doi.org/10.1111/j.1461-0248.2011.01669.x, 2011.

Garibaldi, L. A., Oddi, F. J., Miguez, F. E., Bartomeus, I., Orr, M. C., Jobbágy, E. G., Kremen, C., Schulte, L. A., Hughes, A. C., Bagnato, C., Abramson, G., Bridgewater, P., Carella, D. G., Díaz, S., Dicks, L. V., Ellis, E. C., Goldenberg, M., Huaylla, C. A., Kuperman, M., Locke, H., Mehrabi, Z., Santibañez, F., and Zhu, C.-D.: Working landscapes need at least 20% native habitat, Conservation Letters, 14, e12 773, https://doi.org/10.1111/conl.12773, 2021.

Garnett, S. T., Burgess, N. D., Fa, J. E., Fernández-Llamazares, A., Molnár, Z., Robinson, C. J., Watson, J. E. M., Zander, K. K., Austin, B., Brondizio, E. S., Collier, N. F., Duncan, T., Ellis, E., Geyle, H., Jackson, M. V., Jonas, H., Malmer, P., McGowan, B., Sivongxay, A., and Leiper, I.: A spatial overview of the global importance of Indigenous lands for conservation, Nature Sustainability, 1, 369–374, https://doi.org/10.1038/s41893-018-0100-6, 2018.

Garrison, J. L., Vega, M. A., Shah, R., Mansell, J. R., Nold, B., Raymond, J., Banting, R., Bindlish, R., Larsen, K., Kim, S., Li, W., Kurum, M., Piepmeier, J., Khalifi, H., Tanner, F. A., Horgan, K., Kielbasa, C. E., and Babu, S. R.: SNOOPI: Demonstrating Earth remote sensing using P-band signals of opportunity (SoOp) on a CubeSat, Advances in Space Research, 73, 2855–2879, https://doi.org/10.1016/j.asr.2023.10.050, 2024.

Gasser, T., Ciais, P., and Lewis, S. L.: How the Glasgow Declaration on Forests can help keep alive the 1.5 C target, Proceedings of the National Academy of Sciences, 119, e2200519 119, https://doi.org/10.1073/pnas.2200519119, 2022.

Geissdoerfer, M., Savaget, P., Bocken, N. M. P., and Hultink, E. J.: The Circular Economy – A new sustainability paradigm?, Journal of Cleaner Production, 143, 757–768, https://doi.org/10.1016/j.jclepro.2016.12.048, 2017.

Gielen, M.-C., Johannes, X., Kashe, N., Khumo, G., Zoronxhogo, Z., and Schtickzelle, N.: Monitoring wildlife abundance through track surveys: A capture-mark-recapture inspired approach to assess track detection by certified trackers in the Kalahari, Botswana, Global Ecology and Conservation, 51, e02 924, https://doi.org/10.1016/j.gecco.2024.e02924, 2024.

Gokkon, B.: 'Decolonizing conservation': Q&A with PNG marine activist John Aini, https://news.mongabay.com/2018/07/decolonizing-conservation-qa-with-png-marine-activist-john-aini/, 2018.

Goodness, J., Andersson, E., Anderson, P. M., and Elmqvist, T.: Exploring the links between functional traits and cultural ecosystem services to enhance urban ecosystem management, Ecological Indicators, 70, 597–605, https://doi.org/10.1016/j.ecolind.2016.02.031, 2016.

Griggs, D., Stafford-Smith, M., Gaffney, O., Rockström, J., Öhman, M. C., Shyamsundar, P., Steffen, W., Glaser, G., Kanie, N., and Noble, I.: Sustainable development goals for people and planet, Nature, 495, 305–307, https://doi.org/10.1038/495305a, 2013.

Griscom, B. W., Adams, J., Ellis, P. W., Houghton, R. A., Lomax, G., Miteva, D. A., Schlesinger, W. H., Shoch, D., Siikamäki, J. V., Smith, P., Woodbury, P., Zganjar, C., Blackman, A., Campari, J., Conant, R. T., Delgado, C., Elias, P., Gopalakrishna, T., Hamsik, M. R., Herrero, M., Kiesecker, J., Landis, E., Laestadius, L., Leavitt, S. M., Minnemeyer, S., Polasky, S., Potapov, P., Putz, F. E., Sanderman, J., Silvius, M., Wollenberg, E., and Fargione, J.: Natural climate solutions, Proceedings of the National Academy of Sciences, 114, 11 645–11 650, https://doi.org/10.1073/pnas.1710465114, 2017.

Griscom, B. W., Busch, J., Cook-Patton, S. C., Ellis, P. W., Funk, J., Leavitt, S. M., Lomax, G., Turner, W. R., Chapman, M., Engelmann, J., Gurwick, N. P., Landis, E., Lawrence, D., Malhi, Y., Schindler Murray, L., Navarrete, D., Roe, S., Scull, S., Smith, P., Streck, C., Walker, W. S., and Worthington, T.: National mitigation potential from natural climate solutions in the tropics, Philosophical Transactions of the Royal Society B: Biological Sciences, 375, 20190 126, https://doi.org/10.1098/rstb.2019.0126, 2020.

Groom, B. and Venmans, F.: The social value of offsets, Nature, 619, 768–773, https://doi.org/10.1038/s41586-023-06153-x, 2023.

Guinet, M., Nicolardot, B., and Voisin, A.-S.: Nitrogen benefits of ten legume pre-crops for wheat assessed by field measurements and modelling, European Journal of Agronomy, 120, 126 151, https://doi.org/10.1016/j.eja.2020.126151, 2020.

Haas, O., Prentice, I. C., and Harrison, S. P.: Global environmental controls on wildfire burnt area, size, and intensity, Environmental Research Letters, 17, 065 004, https://doi.org/10.1088/1748-9326/ac6a69, 2022.

Hagger, V., Worthington, T. A., Lovelock, C. E., Adame, M. F., Amano, T., Brown, B. M., Friess, D. A., Landis, E., Mumby, P. J., Morrison, T. H., O'Brien, K. R., Wilson, K. A., Zganjar, C., and Saunders, M. I.: Drivers of global mangrove loss and gain in social-ecological systems, Nature Communications, 13, 6373, https://doi.org/10.1038/s41467-022-33962-x, 2022.

Hahn, T., Sioen, G. B., Gasparatos, A., Elmqvist, T., Brondizio, E., Gómez-Baggethun, E., Folke, C., Setiawati, M. D., Atmaja, T., Arini, E. Y., Jarzebski, M. P., Fukushi, K., and Takeuchi, K.: Insurance value of biodiversity in the Anthropocene is the full resilience value, Ecological Economics, 208, 107 799, https://doi.org/10.1016/j.ecolecon.2023.107799, 2023.

Hammoud, R., Tognin, S., Smythe, M., Gibbons, J., Davidson, N., Bakolis, I., and Mechelli, A.: Smartphone-based ecological momentary assessment reveals an incremental association between natural diversity and mental wellbeing, Scientific Reports, 14, 7051, https://doi.org/10.1038/s41598-024-55940-7, 2024.

Hantson, S., Kelley, D. I., Arneth, A., Harrison, S. P., Archibald, S., Bachelet, D., Forrest, M., Hickler, T., Lasslop, G., Li, F., and others: Quantitative assessment of fire and vegetation properties in simulations with fire-enabled vegetation models from the Fire Model Intercomparison Project, Geoscientific Model Development, 13, 3299–3318, https://doi.org/10.5194/gmd-13-3299-2020, 2020.

Harrison, M. E., Ottay, J. B., D'Arcy, L. J., Cheyne, S. M., Anggodo, Belcher, C., Cole, L., Dohong, A., Ermiasi, Y., Feldpausch, T., and others: Tropical forest and peatland conservation in Indonesia: Challenges and directions, People and Nature, 2, 4–28, https://doi.org/https://doi.org/10.1002/pan3.10060., 2020.

Hartmann, H., Bastos, A., Das, A. J., Esquivel-Muelbert, A., Hammond, W. M., Martínez-Vilalta, J., McDowell, N. G., Powers, J. S., Pugh, T. A., Ruthrof, K. X., and others: Climate change risks to global forest health: emergence of unexpected events of elevated tree mortality worldwide, Annual Review of Plant Biology, 73, 673–702, publisher: Annual Reviews, 2022.

Hasler, N., Williams, C. A., Denney, V. C., Ellis, P. W., Shrestha, S., Terasaki Hart, D. E., Wolff, N. H., Yeo, S., Crowther, T. W., Werden, L. K., and Cook-Patton, S. C.: Accounting for albedo change to identify climate-positive tree cover restoration, Nature Communications, 15, 2275, https://doi.org/10.1038/s41467-024-46577-1, 2024.

Haya, B. K., Evans, S., Brown, L., Bukoski, J., Butsic, V., Cabiyo, B., Jacobson, R., Kerr, A., Potts, M., and Sanchez, D. L.: Comprehensive review of carbon quantification by improved forest management offset protocols, Frontiers in Forests and Global Change, 6, 958 879, https://doi.org/10.3389/ffgc.2023.958879, 2023.

He, T., Lamont, B. B., and Pausas, J. G.: Fire as a key driver of Earth's biodiversity, Biological Reviews, 94, 1983–2010, https://doi.org/https://doi.org/10.1111/brv.12544, 2019.

Hessilt, T. D., Rogers, B. M., Scholten, R. C., Potter, S., Janssen, T. A. J., and Veraverbeke, S.: Geographically divergent trends in snow disappearance timing and fire ignitions across boreal North America, Biogeosciences, 21, 109–129, https://doi.org/10.5194/bg-21-109-2024, 2024.

Hetzer, J., Forrest, M., Ribalaygua, J., Prado-López, C., and Hickler, T.: The fire weather in Europe: large-scale trends towards higher danger, Environmental Research Letters, 19, 084 017, https://doi.org/10.1088/1748-9326/ad5b09, 2024.

Hickel, J.: Less is More: How Degrowth Will Save the World, Random House, 2020.

Hill, M. K.: Understanding environmental pollution, Cambridge University Press, 2020.

Hoegh-Guldberg, O., Poloczanska, E. S., Skirving, W., and Dove, S.: Coral Reef Ecosystems under Climate Change and Ocean Acidification, Frontiers in Marine Science, 4, https://doi.org/10.3389/fmars.2017.00158, 2017.

Hoek van Dijke, A. J., Herold, M., Mallick, K., Benedict, I., Machwitz, M., Schlerf, M., Pranindita, A., Theeuwen, J. J., Bastin, J.-F., and Teuling, A. J.: Shifts in regional water availability due to global tree restoration, Nature Geoscience, 15, 363–368, https://doi.org/10.1038/s41561-022-00935-0, 2022.

Hoel, M. and Sterner, T.: Discounting and relative prices, Climatic Change, 84, 265–280, https://doi.org/10.1007/s10584-007-9255-2, 2007.

Hutton, J., Adams, W. M., and Murombedzi, J. C.: Back to the Barriers? Changing Narratives in Biodiversity Conservation, Forum for Development Studies, 32, 341–370, https://doi.org/10.1080/08039410.2005.9666319, 2005.

Iglesias, V., Balch, J. K., and Travis, W. R.: U.S. fires became larger, more frequent, and more widespread in the 2000s, Science Advances, 8, eabc0020, https://doi.org/10.1126/sciadv.abc0020, 2022.

Ikram, M., Sroufe, R., Awan, U., and Abid, N.: Enabling Progress in Developing Economies: A Novel Hybrid Decision-Making Model for Green Technology Planning, Sustainability, 14, 258, https://doi.org/10.3390/su14010258, 2022.

IPBES: Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Tech. rep., IPBES secretariat, https://doi.org/10.5281/zenodo.6417333, 2019.

IPBES: The Nature Futures Framework, a flexible tool to support the development of scenarios and models of desirable futures for people, nature and Mother Earth, and its methodological guidance, Tech. rep., IPBES secretariat, https://zenodo.org/records/8171339, 2023.

IPCC, ed.: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, 2012.

IPCC: Climate Change 2021 – The Physical Science Basis: Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, 2021.

IPCC: Climate Change 2022 - Mitigation of Climate Change: Working Group III Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, https://doi.org/10.1017/9781009157926, 2022a.

IPCC: Global Warming of 1.5°C: IPCC Special Report on Impacts of Global Warming of 1.5°C above Pre-industrial Levels in Context of Strengthening Response to Climate Change, Sustainable Development, and Efforts to Eradicate Poverty, Cambridge University Press, 2022b.

IPCC: Summary for Policymakers, in: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, pp. 3–34, Cambridge University Press, https://doi.org/10.1017/9781009325844.001, 2022c.

IPCC: Climate Change 2022 – Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, https://doi.org/10.1017/9781009325844, 2023.

Isaacs, M.: Is the blue justice concept a human rights agenda?, http://hdl.handle.net/10566/5087, 2019.

Jain, P., Castellanos-Acuna, D., Coogan, S. C. P., Abatzoglou, J. T., and Flannigan, M. D.: Observed increases in extreme fire weather driven by atmospheric humidity and temperature, Nature Climate Change, 12, 63–70, https://doi.org/10.1038/s41558-021-01224-1, 2022.

Jaureguiberry, P., Titeux, N., Wiemers, M., Bowler, D. E., Coscieme, L., Golden, A. S., Guerra, C. A., Jacob, U., Takahashi, Y., Settele, J., Díaz, S., Molnár, Z., and Purvis, A.: The direct drivers of recent global anthropogenic biodiversity loss, Science Advances, 8, eabm9982, https://doi.org/10.1126/sciadv.abm9982, 2022.

Jiménez-Muñoz, J. C., Mattar, C., Barichivich, J., Santamaría-Artigas, A., Takahashi, K., Malhi, Y., Sobrino, J. A., and Schrier, G. v. d.: Record-breaking warming and extreme drought in the Amazon rainforest during the course of El Niño 2015–2016, Scientific reports, 6, 33 130, https://doi.org/10.1038/srep33130, 2016.

Jones, M. W., Abatzoglou, J. T., Veraverbeke, S., Andela, N., Lasslop, G., Forkel, M., Smith, A. J. P., Burton, C., Betts, R. A., van der Werf, G. R., Sitch, S., Canadell, J. G., Santín, C., Kolden, C., Doerr, S. H., and Le Quéré, C.: Global and Regional Trends and Drivers of Fire Under Climate Change, Reviews of Geophysics, 60, 1–76, https://doi.org/10.1029/2020RG000726, 2022.

Jones, M. W., Kelley, D. I., Burton, C. A., Di Giuseppe, F., Barbosa, M. L. F., Brambleby, E., Hartley, A. J., Lombardi, A., Mataveli, G., McNorton, J. R., Spuler, F. R., Wessel, J. B., Abatzoglou, J. T., Anderson, L. O., Andela, N., Archibald, S., Armenteras, D., Burke, E., Carmenta, R., Chuvieco, E., Clarke, H., Doerr, S. H., Fernandes, P. M., Giglio, L., Hamilton, D. S., Hantson, S., Harris, S., Jain, P., Kolden, C. A., Kurvits, T., Lampe, S., Meier, S., New, S., Parrington, M., Perron, M. M. G., Qu, Y., Ribeiro, N. S., Saharjo, B. H., San-Miguel-

Ayanz, J., Shuman, J. K., Tanpipat, V., van der Werf, G. R., Veraverbeke, S., and Xanthopoulos, G.: State of Wildfires 2023-24, Earth System Science Data Discussions, pp. 1–124, https://doi.org/10.5194/essd-2024-218, 2024.

Jones, S. C. and Pippin, J. S.: Towards principles and policy levers for advancing living shorelines, Journal of Environmental Management, 311, 114 695, https://doi.org/10.1016/j.jenvman.2022.114695, 2022.

Jones, S. K., Sánchez, A. C., Beillouin, D., Juventia, S. D., Mosnier, A., Remans, R., and Estrada Carmona, N.: Achieving win-win outcomes for biodiversity and yield through diversified farming, Basic and Applied Ecology, 67, 14–31, https://doi.org/10.1016/j.baae.2022.12.005, 2023.

Jurkus, E., Povilanskas, R., Razinkovas-Baziukas, A., and Taminskas, J.: Current Trends and Issues in Applications of Remote Sensing in Coastal and Marine Conservation, Earth, 3, 433–447, https://doi.org/10.3390/earth3010026, 2022.

Kareiva, P., Lalasz, R., and Marvier, M.: Conservation in the Anthropocene: beyond solitude and fragility, Breakthrough Journal, 2, 29–37, 2011.

Kim, H., Peterson, G. D., Cheung, W. W. L., Ferrier, S., Alkemade, R., Arneth, A., Kuiper, J. J., Okayasu, S., Pereira, L., Acosta, L. A., Chaplin-Kramer, R., den Belder, E., Eddy, T. D., Johnson, J. A., Karlsson-Vinkhuyzen, S., Kok, M. T. J., Leadley, P., Leclère, D., Lundquist, C. J., Rondinini, C., Scholes, R. J., Schoolenberg, M. A., Shin, Y.-J., Stehfest, E., Stephenson, F., Visconti, P., van Vuuren, D., Wabnitz, C. C. C., José Alava, J., Cuadros-Casanova, I., Davies, K. K., Gasalla, M. A., Halouani, G., Harfoot, M., Hashimoto, S., Hickler, T., Hirsch, T., Kolomytsev, G., Miller, B. W., Ohashi, H., Gabriela Palomo, M., Popp, A., Paco Remme, R., Saito, O., Rashid Sumalia, U., Willcock, S., and Pereira, H. M.: Towards a better future for biodiversity and people: Modelling Nature Futures, Global Environmental Change, 82, 102 681, https://doi.org/10.1016/j.gloenvcha.2023.102681, 2023.

Knapp, M., Teder, T., Lukas, V., Štrobl, M., Knappová, J., Landis, D. A., and González, E.: Ecologically-Informed Precision Conservation: A framework for increasing biodiversity in intensively managed agricultural landscapes with minimal sacrifice in crop production, Biological Conservation, 288, 110 343, https://doi.org/10.1016/j.biocon.2023.110343, 2023.

Koch, A. and Kaplan, J. O.: Tropical forest restoration under future climate change, Nature Climate Change, 12, 279–283, https://doi.org/10.1038/s41558-022-01289-6, 2022.

Koh, N. S., Ituarte-Lima, C., and Hahn, T.: Mind the Compliance Gap: How Insights from International Human Rights Mechanisms Can Help to Implement the Convention on Biological Diversity, Transnational Environmental Law, 11, 39–67, https://doi.org/10.1017/S2047102521000169, 2022.

Konijnendijk, C. C.: Evidence-based guidelines for greener, healthier, more resilient neighbourhoods: Introducing the 3–30–300 rule, Journal of forestry research, 34, 821–830, https://doi.org/10.1007/s11676-022-01523-z, 2023.

Korhonen, J., Nuur, C., Feldmann, A., and Birkie, S. E.: Circular economy as an essentially contested concept, Journal of Cleaner Production, 175, 544–552, https://doi.org/10.1016/j.jclepro.2017.12.111, 2018.

Kreider, M. R., Higuera, P. E., Parks, S. A., Rice, W. L., White, N., and Larson, A. J.: Fire suppression makes wildfires more severe and accentuates impacts of climate change and fuel accumulation, Nature Communications, 15, 2412, https://doi.org/10.1038/s41467-024-46702-0, 2024.

Krishnan, R. and Gopan, G.: A comprehensive review of lithium extraction: From historical perspectives to emerging technologies, storage, and environmental considerations, Cleaner Engineering and Technology, 20, 100 749, https://doi.org/10.1016/j.clet.2024.100749, 2024.

Köhler, J., Geels, F. W., Kern, F., Markard, J., Onsongo, E., Wieczorek, A., Alkemade, F., Avelino, F., Bergek, A., Boons, F., Fünfschilling, L., Hess, D., Holtz, G., Hyysalo, S., Jenkins, K., Kivimaa, P., Martiskainen, M., McMeekin, A., Mühlemeier, M. S., Nykvist, B., Pel, B., Raven, R., Rohracher, H., Sandén, B., Schot, J., Sovacool, B., Turnheim, B., Welch, D., and Wells, P.: An agenda for sustainability transitions research: State of the art and future directions, Environmental Innovation and Societal Transitions, 31, 1–32, https://doi.org/10.1016/j.eist.2019.01.004, 2019.

Lal, P., Singh, G., Das, N. N., Entekhabi, D., Lohman, R., Colliander, A., Pandey, D. K., and Setia, R. K.: A multi-scale algorithm for the NISAR mission high-resolution soil moisture product, Remote Sensing of Environment, 295, 113 667, https://doi.org/10.1016/j.rse.2023.113667, 2023.

Lalonde, M., Drenkhan, F., Rau, P., Baiker, J. R., and Buytaert, W.: Scientific evidence of the hydrological impacts of nature-based solutions at the catchment scale, WIREs Water, n/a, e1744, https://doi.org/10.1002/wat2.1744, 2024.

Lanjouw, A.: De-colonizing conservation in a global world, American Journal of Primatology, 83, e23 258, https://doi.org/10.1002/ajp.23258, 2021.

Lapola, D. M., Pinho, P., Barlow, J., Aragão, L. E., Berenguer, E., Carmenta, R., Liddy, H. M., Seixas, H., Silva, C. V., Silva-Junior, C. H., and others: The drivers and impacts of Amazon forest degradation, Science, 379, eabp8622, https://doi.org/10.1126/science.abp8622, 2023.

Latawiec, A. E., Strassburg, B. B. N., Silva, D., Alves-Pinto, H. N., Feltran-Barbieri, R., Castro, A., Iribarrem, A., Rangel, M. C., Kalif, K. A. B., Gardner, T., and Beduschi, F.: Improving land management in Brazil: A perspective from producers, Agriculture, Ecosystems & Environment, 240, 276–286, https://doi.org/10.1016/j.agee.2017.01.043, 2017.

Lawrence, D. and Vandecar, K.: Effects of tropical deforestation on climate and agriculture, Nature Climate Change, 5, 27–36, https://doi.org/10.1038/nclimate2430, 2015.

Le Quéré, C., Andres, R. J., Boden, T., Conway, T., Houghton, R. A., House, J. I., Marland, G., Peters, G. P., van der Werf, G. R., Ahlström, A., Andrew, R. M., Bopp, L., Canadell, J. G., Ciais, P., Doney, S. C., Enright, C., Friedlingstein, P., Huntingford, C., Jain, A. K., Jourdain, C., Kato, E., Keeling, R. F., Klein Goldewijk, K., Levis, S., Levy, P., Lomas, M., Poulter, B., Raupach, M. R., Schwinger, J., Sitch, S., Stocker, B. D., Viovy, N., Zaehle, S., and Zeng, N.: The global carbon budget 1959–2011, Earth System Science Data, 5, 165–185, https://doi.org/10.5194/essd-5-165-2013, 2013.

Leach, M., Reyers, B., Bai, X., Brondizio, E. S., Cook, C., Díaz, S., Espindola, G., Scobie, M., Stafford-Smith, M., and Subramanian, S. M.: Equity and sustainability in the Anthropocene: a social–ecological systems perspective on their intertwined futures, Global Sustainability, 1, https://doi.org/10.1017/sus.2018.12, 2018.

Leal Filho, W., Barbir, J., and Preziosi, R.: Handbook of climate change and biodiversity, Springer, 2019.

Lechner, A. M., Stein, A., Jones, S. D., and Ferwerda, J. G.: Remote sensing of small and linear features: Quantifying the effects of patch size and length, grid position and detectability on land cover mapping, Remote Sensing of Environment, 113, 2194–2204, https://doi.org/10.1016/j.rse.2009.06.002, 2009.

Leclère, D., Obersteiner, M., Barrett, M., Butchart, S. H., Chaudhary, A., De Palma, A., DeClerck, F. A., Di Marco, M., Doelman, J. C., Dürauer, M., and others: Bending the curve of terrestrial biodiversity needs an integrated strategy, Nature, 585, 551–556, https://doi.org/10.1038/s41586-020-2705-y, 2020.

Lee, H., Calvin, K., Dasgupta, D., Krinner, G., Mukherji, A., Thorne, P., Trisos, C., Romero, J., Aldunce, P., Barret, K., Blanco, G., Cheung, W. W. L., Connors, S. L., Denton, F., Diongue-Niang, A., Dodman, D., Garschagen, M., Geden, O., Hayward, B., Jones, C., Jotzo, F., Krug, T., Lasco, R., Lee, Y.-Y., Masson-Delmotte, V., Meinshausen, M., Mintenbeck, K., Mokssit, A., Otto, F. E. L., Pathak, M., Pirani, A., Poloczanska, E., Pörtner, H.-O., Revi, A., Roberts, D. C., Roy, J., Ruane, A. C., Skea, J., Shukla, P. R., Slade, R., Slangen, A., Sokona, Y., Sörensson, A. A., Tignor, M., van Vuuren, D., Wei, Y.-M., Winkler, H., Zhai, P., Zommers, Z., Hourcade, J.-C., Johnson, F. X., Pachauri, S., Simpson, N. P., Singh, C., Thomas, A., Totin, E., Arias, P., Bustamante, M., Elgizouli, I., Flato, G., Howden, M., Méndez-Vallejo, C., Pereira, J. J., Pichs-Madruga, R., Rose, S. K., Saheb, Y., Sánchez Rodríguez, R., Ürge Vorsatz, D., Xiao, C., Yassaa, N., Alegría, A., Armour, K., Bednar-Friedl, B., Blok, K., Cissé, G., Dentener, F., Eriksen, S., Fischer, E., Garner, G., Guivarch, C., Haasnoot, M., Hansen, G., Hauser, M., Hawkins, E., Hermans, T., Kopp, R., Leprince-Ringuet, N., Lewis, J., Ley, D., Ludden, C., Niamir, L., Nicholls, Z., Some, S., Szopa, S., Trewin, B., van der Wijst, K.-I., Winter, G., Witting, M., Birt, A., Ha, M., Romero, J., Kim, J., Haites, E. F., Jung, Y., Stavins, R., Birt, A., Ha, M., Orendain, D. J. A., Ignon, L., Park, S., and Park, Y.: IPCC, 2023: Climate Change 2023: Synthesis Report, Summary for Policymakers. 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., Tech. rep., IPCC, https://doi.org/10.59327/IPCC/AR6-9789291691647.001, 2023.

Leeuwen, S. v., Legge, S., and Rumpff, L.: Australia's Megafires: Biodiversity Impacts and Lessons from 2019-2020, Csiro Publishing, 2023.

Legge, S., Rumpff, L., Garnett, S. T., and Woinarski, J. C.: Loss of terrestrial biodiversity in Australia: Magnitude, causation, and response, Science, 381, 622–631, https://doi.org/10.1126/science.adg7870, 2023.

Leite-Filho, A. T., Soares-Filho, B. S., Davis, J. L., Abrahão, G. M., and Börner, J.: Deforestation reduces rainfall and agricultural revenues in the Brazilian Amazon, Nature Communications, 12, 2591, https://doi.org/10.1038/s41467-021-22840-7, 2021.

Lenton, T. M., Rockström, J., Gaffney, O., Rahmstorf, S., Richardson, K., Steffen, W., and Schellnhuber, H. J.: Climate tipping points — too risky to bet against, Nature, 575, 592–595, https://doi.org/10.1038/d41586-019-03595-0, 2019.

Levasseur, A., Lesage, P., Margni, M., Brandão, M., and Samson, R.: Assessing temporary carbon sequestration and storage projects through land use, land-use change and forestry: comparison of dynamic life cycle assessment with ton-year approaches, Climatic Change, 115, 759–776, https://doi.org/10.1007/s10584-012-0473-x, 2012.

Lewis, S. L., Brando, P. M., Phillips, O. L., Van Der Heijden, G. M., and Nepstad, D.: The 2010 amazon drought, Science, 331, 554–554, https://doi.org/10.1126/science.1200807, 2011.

Li, W., Migliavacca, M., Forkel, M., Denissen, J. M. C., Reichstein, M., Yang, H., Duveiller, G., Weber, U., and Orth, R.: Widespread increasing vegetation sensitivity to soil moisture, Nature Communications, 13, 3959, https://doi.org/10.1038/s41467-022-31667-9, 2022.

Lichtenberg, E. M., Kennedy, C. M., Kremen, C., Batáry, P., Berendse, F., Bommarco, R., Bosque-Pérez, N. A., Carvalheiro, L. G., Snyder, W. E., Williams, N. M., Winfree, R., Klatt, B. K., Åström, S., Benjamin, F., Brittain, C., Chaplin-Kramer, R., Clough, Y., Danforth, B., Diekötter, T., Eigenbrode, S. D., Ekroos, J., Elle, E., Freitas, B. M., Fukuda, Y., Gaines-Day, H. R., Grab, H., Gratton, C., Holzschuh, A., Isaacs, R., Isaia, M., Jha, S., Jonason, D., Jones, V. P., Klein, A.-M., Krauss, J., Letourneau, D. K., Macfadyen, S., Mallinger, R. E., Martin, E. A., Martinez, E., Memmott, J., Morandin, L., Neame, L., Otieno, M., Park, M. G., Pfiffner, L., Pocock, M. J. O., Ponce, C., Potts, S. G., Poveda, K., Ramos, M., Rosenheim, J. A., Rundlöf, M., Sardiñas, H., Saunders, M. E., Schon, N. L., Sciligo, A. R., Sidhu, C. S., Steffan-Dewenter, I., Tscharntke, T., Veselý, M., Weisser, W. W., Wilson, J. K., and Crowder, D. W.: A global synthesis of the effects of diversified farming systems on arthropod diversity within fields and across agricultural landscapes, Global Change Biology, 23, 4946–4957, https://doi.org/10.1111/gcb.13714, 2017.

Litvinenko, V., Bowbrik, I., Naumov, I., and Zaitseva, Z.: Global guidelines and requirements for professional competencies of natural resource extraction engineers: Implications for ESG principles and sustainable development goals, Journal of Cleaner Production, 338, 130 530, https://doi.org/10.1016/j.jclepro.2022.130530, 2022.

Liu, J., Dou, Y., Batistella, M., Challies, E., Connor, T., Friis, C., Millington, J. D., Parish, E., Romulo, C. L., Silva, R. F. B., Triezenberg, H., Yang, H., Zhao, Z., Zimmerer, K. S., Huettmann, F., Treglia, M. L., Basher, Z., Chung, M. G., Herzberger, A., Lenschow, A., Mechiche-Alami, A., Newig, J., Roche, J., and Sun, J.: Spillover systems in a telecoupled Anthropocene: typology, methods, and governance for global sustainability, Current Opinion in Environmental Sustainability, 33, 58–69, https://doi.org/10.1016/j.cosust.2018.04.009, 2018a.

Liu, X., Trogisch, S., He, J.-S., Niklaus, P. A., Bruelheide, H., Tang, Z., Erfmeier, A., Scherer-Lorenzen, M., Pietsch, K. A., Yang, B., and others: Tree species richness increases ecosystem carbon storage in subtropical forests, Proceedings of the Royal Society B, 285, 20181 240, https://doi.org/10.1098/rspb.2018.1240, 2018b.

Lovejoy, T. E. and Nobre, C.: Amazon Tipping Point, Science Advances, 4, eaat2340, https://doi.org/10.1126/sciadv.aat2340, 2018.

Luke, S. H., Slade, E. M., Gray, C. L., Annammala, K. V., Drewer, J., Williamson, J., Agama, A. L., Ationg, M., Mitchell, S. L., Vairappan, C. S., and Struebig, M. J.: Riparian buffers in tropical agriculture: Scientific support, effectiveness and directions for policy, Journal of Applied Ecology, 56, 85–92, https://doi.org/10.1111/1365-2664.13280, 2019.

Luo, H., Quaas, J., and Han, Y.: Decreased cloud cover partially offsets the cooling effects of surface albedo change due to deforestation, Nature Communications, 15, 7345, publisher: Nature Publishing Group UK London, 2024.

Löfqvist, S., Kleinschroth, F., Bey, A., de Bremond, A., DeFries, R., Dong, J., Fleischman, F., Lele, S., Martin, D. A., Messerli, P., Meyfroidt, P., Pfeifer, M., Rakotonarivo, S. O., Ramankutty, N., Ramprasad, V., Rana, P., Rhemtulla, J. M., Ryan, C. M., Vieira, I. C. G., Wells, G. J., and Garrett, R. D.: How Social Considerations Improve the Equity and Effectiveness of Ecosystem Restoration, BioScience, 73, 134–148, https://doi.org/10.1093/biosci/biac099, 2023.

Lüdeke-Freund, F., Gold, S., and Bocken, N. M. P.: A Review and Typology of Circular Economy Business Model Patterns, Journal of Industrial Ecology, 23, 36–61, https://doi.org/10.1111/jiec.12763, 2019.

Mabele, M. B., Krauss, J. E., and Kiwango, W.: Going Back to the Roots: Ubuntu: and Just Conservation in Southern Africa, Conservation and Society, 20, 92–102, https://doi.org/10.4103/cs.cs_33_21, 2022.

MacCarthy, J., Tyukavina, A., Weisse, M. J., Harris, N., and Glen, E.: Extreme wildfires in Canada and their contribution to global loss in tree cover and carbon emissions in 2023, Global Change Biology, 30, e17 392, https://doi.org/10.1111/gcb.17392, _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/gcb.17392, 2024.

Magerl, A., Gingrich, S., Matej, S., Cunfer, G., Forrest, M., Lauk, C., Schlaffer, S., Weidinger, F., Yuskiw, C., and Erb, K.-H.: The Role of Wildfires in the Interplay of Forest Carbon Stocks and Wood Harvest in the Contiguous United States During the 20th Century, Global Biogeochemical Cycles, 37, e2023GB007 813, https://doi.org/10.1029/2023GB007813, 2023.

Mahecha, M. D., Bastos, A., Bohn, F. J., Eisenhauer, N., Feilhauer, H., Hickler, T., Kalesse-Los, H., Migliavacca, M., Otto, F. E. L., Peng, J., Sippel, S., Tegen, I., Weigelt, A., Wendisch, M., Wirth, C., Al-Halbouni, D., Deneke, H., Doktor, D., Dunker, S., Duveiller, G., Ehrlich, A., Foth, A., García-García, A., Guerra, C. A., Guimarães-Steinicke, C., Hartmann, H., Henning, S., Herrmann, H., Hu, P., Ji, C., Kattenborn, T., Kolleck, N., Kretschmer, M., Kühn, I., Luttkus, M. L., Maahn, M., Mönks, M., Mora, K., Pöhlker, M., Reichstein, M., Rüger, N., Sánchez-Parra, B., Schäfer, M., Stratmann, F., Tesche, M., Wehner, B., Wieneke, S., Winkler, A. J., Wolf, S., Zaehle, S., Zscheischler, J., and Quaas, J.: Biodiversity and Climate Extremes: Known Interactions and Research Gaps, Earth's Future, 12, e2023EF003 963, https://doi.org/10.1029/2023EF003963, 2024.

Makarieva, A. M. and Gorshkov, V. G.: Biotic pump of atmospheric moisture as driver of the hydrological cycle on land, Hydrology and Earth System Sciences, 11, 1013–1033, https://doi.org/10.5194/hess-11-1013-2007, 2007.

Mancini, L., Eslava, N. A., Traverso, M., and Mathieux, F.: Assessing impacts of responsible sourcing initiatives for cobalt: Insights from a case study, Resources Policy, 71, 102 015, https://doi.org/10.1016/j.resourpol.2021.102015, 2021.

Manning, P.: A global target for semi-natural land cover within human dominated landscapes?, One Earth, 7, 180–181, https://doi.org/10.1016/j.oneear.2024.01.007, publisher: Elsevier, 2024.

Marja, R., Tscharntke, T., and Batáry, P.: Increasing landscape complexity enhances species richness of farmland arthropods, agri-environment schemes also abundance – A meta-analysis, Agriculture, Ecosystems & Environment, 326, 107 822, https://doi.org/10.1016/j.agee.2021.107822, 2022.

Maron, M., Juffe-Bignoli, D., Krueger, L., Kiesecker, J., Kümpel, N. F., ten Kate, K., Milner-Gulland, E., Arlidge, W. N. S., Booth, H., Bull, J. W., Starkey, M., Ekstrom, J. M., Strassburg, B., Verburg, P. H., and Watson, J. E. M.: Setting robust biodiversity goals, Conservation Letters, 14, e12 816, https://doi.org/10.1111/conl.12816, 2021.

Marquez, V., Carbone, L. M., Jiménez-Escobar, N. D., Britos, A. H., Aguilar, R., and Zamudio, F.: Local ecological knowledge of forage plants for goat farming and perceptions about pollination of tree species in the arid Chaco, Journal of Arid Environments, 222, 105 167, publisher: Elsevier, 2024.

Marris, E.: Rambunctious garden: saving nature in a post-wild world, Bloomsbury Publishing USA, 2013.

Martin, A., Armijos, M. T., Coolsaet, B., Dawson, N., A. S. Edwards, G., Few, R., Gross-Camp, N., Rodriguez, I., Schroeder, H., G. L. Tebboth, M., and White, C. S.: Environmental Justice and Transformations to Sustainability, Environment: Science and Policy for Sustainable Development, 62, 19–30, https://doi.org/10.1080/00139157.2020.1820294, 2020.

Martin, A., Gomez-Baggethun, E., Quaas, M., Rozzi, R., Tauro, A., Faith, D. P., Kumar, R., O'Farrell, P., and Pascual, U.: Plural values of nature help to understand contested pathways to sustainability, One Earth, 7, 806–819, https://doi.org/10.1016/j.oneear.2024.04.003, 2024.

Martin, E. A., Dainese, M., Clough, Y., Báldi, A., Bommarco, R., Gagic, V., Garratt, M. P., Holzschuh, A., Kleijn, D., Kovács-Hostyánszki, A., and others: The interplay of landscape composition and configuration: new pathways to manage functional biodiversity and agroecosystem services across Europe, Ecology letters, 22, 1083–1094, https://doi.org/10.1111/ele.13265, 2019.

Martin, L. J., Blossey, B., and Ellis, E.: Mapping where ecologists work: biases in the global distribution of terrestrial ecological observations, Frontiers in Ecology and the Environment, 10, 195–201, https://doi.org/10.1890/110154, 2012.

Martin, M. A., Boakye, E. A., Boyd, E., Broadgate, W., Bustamante, M., Canadell, J. G., Carr, E. R., Chu, E. K., Cleugh, H., Csevár, S., and others: Ten new insights in climate science 2022, Global Sustainability, 5, e20, https://doi.org/10.1017/sus.2022.17, 2022.

Maskell, L. C., Radbourne, A., Norton, L. R., Reinsch, S., Alison, J., Bowles, L., Geudens, K., and Robinson, D. A.: Functional Agro-Biodiversity: An Evaluation of Current Approaches and Outcomes, Land, 12, 2078, https://doi.org/10.3390/land12112078, 2023.

Massarella, K., Nygren, A., Fletcher, R., Büscher, B., Kiwango, W. A., Komi, S., Krauss, J. E., Mabele, M. B., McInturff, A., Sandroni, L. T., Alagona, P. S., Brockington, D., Coates, R., Duffy, R., Ferraz, K. M. P. M. B., Koot, S., Marchini, S., and Percequillo, A. R.: Transformation beyond conservation: how critical social science can contribute to a radical new agenda in biodiversity conservation, Current Opinion in Environmental Sustainability, 49, 79–87, https://doi.org/10.1016/j.cosust.2021.03.005, 2021.

Massarella, K., Krauss, J., Kiwango, W., and Fletcher, R.: Convivial Conservation: From Principles to Practice, Mayfly Books, 2023.

Matias, A., Carrasco, A. R., Pinto, B., and Reis, J.: The role of art in coastal and marine sustainability, Cambridge Prisms: Coastal Futures, 1, e25, https://doi.org/10.1017/cft.2023.13, 2023.

Matthews, H. D., Zickfeld, K., Dickau, M., MacIsaac, A. J., Mathesius, S., Nzotungicimpaye, C.-M., and Luers, A.: Temporary nature-based carbon removal can lower peak warming in a well-below 2 °C scenario, Communications Earth & Environment, 3, 1–8, https://doi.org/10.1038/s43247-022-00391-z, 2022.

Matthews, H. D., Zickfeld, K., Koch, A., and Luers, A.: Accounting for the climate benefit of temporary carbon storage in nature, Nature Communications, 14, 5485, https://doi.org/DOI:10.1038/s41467-023-41242-5, 2023.

McDermott, C. L., Montana, J., Bennett, A., Gueiros, C., Hamilton, R., Hirons, M., Maguire-Rajpaul, V. A., Parry, E., and Picot, L.: Transforming land use governance: Global targets without equity miss the mark, Environmental Policy and Governance, 33, 245–257, https://doi.org/10.1002/eet.2027, 2023.

Meijaard, E., Brooks, T. M., Carlson, K. M., Slade, E. M., Garcia-Ulloa, J., Gaveau, D. L., Lee, J. S. H., Santika, T., Juffe-Bignoli, D., Struebig, M. J., and others: The environmental impacts of palm oil in context, Nature plants, 6, 1418–1426, https://doi.org/10.1038/s41477-020-00813-w, 2020.

Meinshausen, M., Lewis, J., McGlade, C., Gütschow, J., Nicholls, Z., Burdon, R., Cozzi, L., and Hackmann, B.: Realization of Paris Agreement pledges may limit warming just below 2 °C, Nature, 604, 304–309, https://doi.org/10.1038/s41586-022-04553-z, 2022.

Meli, P., Holl, K. D., Benayas, J. M. R., Jones, H. P., Jones, P. C., Montoya, D., and Mateos, D. M.: A global review of past land use, climate, and active vs. passive restoration effects on forest recovery, PLOS ONE, 12, e0171 368, https://doi.org/10.1371/journal.pone.0171368, 2017.

Merino, R. and Gustafsson, M.-T.: Localizing the indigenous environmental steward norm: The making of conservation and territorial rights in Peru, Environmental Science & Policy, 124, 627–634, https://doi.org/10.1016/j.envsci.2021.07.005, 2021.

M'Gonigle, L. K., Ponisio, L. C., Cutler, K., and Kremen, C.: Habitat restoration promotes pollinator persistence and colonization in intensively managed agriculture, Ecological Applications, 25, 1557–1565, https://doi.org/10.1890/14-1863.1, 2015.

Miralles, D. G., Gentine, P., Seneviratne, S. I., and Teuling, A. J.: Land-atmospheric feedbacks during droughts and heatwaves: state of the science and current challenges, Annals of the New York Academy of Sciences, 1436, 19–35, https://doi.org/10.1111/nyas.13912, 2019.

Mohamed, A., DeClerck, F., Verburg, P. H., Obura, D., Abrams, J. F., Zafra-Calvo, N., Rocha, J., Estrada-Carmona, N., Fremier, A., Jones, S. K., and others: Securing Nature's Contributions to People requires at least 20%–25%(semi-) natural habitat in human-modified landscapes, One Earth, 7, 59–71, https://doi.org/10.1016/j.oneear.2023.12.008, 2024.

Molnár, Z., Aumeeruddy-Thomas, Y., Babai, D., Díaz, S., Garnett, S. T., Hill, R., Bates, P., Brondízio, E. S., Cariño, J., Demeter, L., and others: Towards richer knowledge partnerships between ecology and ethnoecology, Trends in ecology & evolution, 39, 109–115, 2024.

Moranta, J., Torres, C., Murray, I., Hidalgo, M., Hinz, H., and Gouraguine, A.: Transcending capitalism growth strategies for biodiversity conservation, Conservation Biology, 36, e13 821, https://doi.org/10.1111/cobi.13821, 2022.

Müller, U. K., Stock, J. H., and Watson, M. W.: An econometric model of international growth dynamics for long-horizon forecasting, Review of Economics and Statistics, 104, 857–876, https://doi.org/10.1162/rest_a_00997, 2022.

Neidermeier, A. N., Zagaria, C., Pampanoni, V., West, T. A. P., and Verburg, P. H.: Mapping opportunities for the use of land management strategies to address fire risk in Europe, Journal of Environmental Management, 346, 118 941, https://doi.org/10.1016/j.jenvman.2023.118941, 2023.

Nelson, J. A., Walther, S., Gans, F., Kraft, B., Weber, U., Novick, K., Buchmann, N., Migliavacca, M., Wohlfahrt, G., Šigut, L., Ibrom, A., Papale, D., Göckede, M., Duveiller, G., Knohl, A., Hörtnagl, L., Scott, R. L., Zhang, W., Hamdi, Z. M., Reichstein, M., Aranda-Barranco, S., Ardö, J., Op de Beeck, M., Billdesbach, D., Bowling, D., Bracho, R., Brümmer, C., Camps-Valls, G., Chen, S., Cleverly, J. R., Desai, A., Dong, G., El-Madany, T. S., Euskirchen, E. S., Feigenwinter, I., Galvagno, M., Gerosa, G., Gielen, B., Goded, I., Goslee, S., Gough, C. M., Heinesch, B., Ichii, K., Jackowicz-Korczynski, M. A., Klosterhalfen, A., Knox, S., Kobayashi, H., Kohonen, K.-M., Korkiakoski, M., Mammarella, I., Mana, G., Marzuoli, R., Matamala, R., Metzger, S., Montagnani, L., Nicolini, G., O'Halloran, T., Ourcival, J.-M., Peichl, M., Pendall, E., Ruiz Reverter, B., Roland, M., Sabbatini, S., Sachs, T., Schmidt, M., Schwalm, C. R., Shekhar, A., Silberstein, R., Silveira, M. L., Spano, D., Tagesson, T., Tramontana, G., Trotta, C., Turco, F., Vesala, T., Vincke, C., Vitale, D., Vivoni, E. R., Wang, Y., Woodgate, W., Yepez, E. A., Zhang, J., Zona, D., and Jung, M.: X-BASE: the first terrestrial carbon and water flux products from an extended data-driven scaling framework, FLUXCOM-X, EGUsphere, pp. 1–51, https://doi.org/10.5194/egusphere-2024-165, 2024.

Nelson, K., Thompson, D., Hopkinson, C., Petrone, R., and Chasmer, L.: Peatland-fire interactions: A review of wildland fire feedbacks and interactions in Canadian boreal peatlands, Science of The Total Environment, 769, 145 212, https://doi.org/10.1016/j.scitotenv.2021.145212, 2021.

Newell, P. and Taylor, O.: Fiddling while the planet burns? COP25 in perspective, in: Economics and Climate Emergency, Routledge, 2022.

Nie, M., Liu, W., Pennings, S. C., and Li, B.: Lessons from the invasion of in coastal China, Ecology, 104, e3874, https://doi.org/10.1002/ecy.3874, 2023.

NOAA: Coastal Blue Carbon, https://oceanservice.noaa.gov/ecosystems/coastal-blue-carbon/#, 2024.

Nodo, P., Childs, A.-R., Pattrick, P., and James, N. C.: The nursery function of shallow nearshore and estuarine benthic habitats for demersal fishes, Estuarine, Coastal and Shelf Science, 280, 108 168, https://doi.org/10.1016/j.ecss.2022.108168, 2023.

Nordhaus, W.: Climate change: The ultimate challenge for economics, American Economic Review, 109, 1991–2014, https://doi.org/DOI: 10.1257/aer.109.6.1991, 2019.

Northey, S. A., Mudd, G. M., Werner, T. T., Jowitt, S. M., Haque, N., Yellishetty, M., and Weng, Z.: The exposure of global base metal resources to water criticality, scarcity and climate change, Global Environmental Change, 44, 109–124, https://doi.org/10.1016/j.gloenvcha.2017.04.004, 2017.

O., S. and Orth, R.: Global soil moisture data derived through machine learning trained with in-situ measurements, Scientific Data, 8, 170, https://doi.org/10.1038/s41597-021-00964-1, 2021.

O'Brien, K. and Barnett, J.: Global Environmental Change and Human Security, Annual Review of Environment and Resources, 38, 373–391, https://doi.org/10.1146/annurev-environ-032112-100655, 2013.

Obura, D. O., DeClerck, F., Verburg, P. H., Gupta, J., Abrams, J. F., Bai, X., Bunn, S., Ebi, K. L., Gifford, L., Gordon, C., Jacobson, L., Lenton, T. M., Liverman, D., Mohamed, A., Prodani, K., Rocha, J. C., Rockström, J., Sakschewski, B., Stewart-Koster, B., van Vuuren, D., Winkelmann, R., and Zimm, C.: Achieving a nature- and people-positive future, One Earth, 6, 105–117, https://doi.org/10.1016/j.oneear.2022.11.013, 2023.

Ochieng, A., Koh, N. S., and Koot, S.: Compatible with Conviviality? Exploring African Ecotourism and Sport Hunting for Transformative Conservation, Conservation and Society, 21, 38, https://doi.org/10.4103/cs.cs_42_21, 2023.

OECD: Towards Sustainable Land Use: Aligning Biodiversity, Climate and Food Policies, Organisation for Economic Co-operation and Development, Paris, https://www.oecd-ilibrary.org/environment/towards-sustainable-land-use_3809b6a1-en, 2020.

Ojeda, J., Salomon, A. K., Rowe, J. K., and Ban, N. C.: Reciprocal contributions between people and nature: a conceptual intervention, BioScience, 72, 952–962, https://doi.org/10.1093/biosci/biac053, 2022.

Oliveira, M. R., Ferreira, B. H., Souza, E. B., Lopes, A. A., Bolzan, F. P., Roque, F. O., Pott, A., Pereira, A. M., Garcia, L. C., Damasceno Jr, G. A., and others: Indigenous brigades change the spatial patterns of wildfires, and the influence of climate on fire regimes, Journal of Applied Ecology, 59, 1279–1290, https://doi.org/10.1111/1365-2664.14139, 2022.

Orlove, B., Sherpa, P., Dawson, N., Adelekan, I., Alangui, W., Carmona, R., Coen, D., Nelson, M. K., Reyes-García, V., Rubis, J., Sanago, G., and Wilson, A.: Placing diverse knowledge systems at the core of transformative climate research, Ambio, 52, 1431–1447, https://doi.org/10.1007/s13280-023-01857-w, 2023.

Ostrom, E.: A General Framework for Analyzing Sustainability of Social-Ecological Systems, Science, 325, 419–422, https://doi.org/10.1126/science.1172133, 2009.

Pachauri, R. K., Allen, M. R., Barros, V. R., Broome, J., Cramer, W., Christ, R., Church, J. A., Clarke, L., Dahe, Q., Dasgupta, P., Dubash, N. K., Edenhofer, O., Elgizouli, I., Field, C. B., Forster, P., Friedlingstein, P., Fuglestvedt, J., Gomez-Echeverri, L., Hallegatte, S., Hegerl, G., Howden, M., Jiang, K., Jimenez Cisneroz, B., Kattsov, V., Lee, H., Mach, K. J., Marotzke, J., Meyer, L., Minx, J., Mulugetta, Y., O'Brien, K., Oppenheimer, M., Pereira, J. J., Pichs-Madruga, R., Plattner, G.-K., Pörtner, H.-O., Power, S. B., Preston, B., Ravindranath, N. H., Reisinger, A., Riahi, K., Rusticucci, M., Scholes, R., Seyboth, K., Sokona, Y., Stavins, R., Stocker, T. F., Tschakert, P., van Vuuren, D., and van Ypserle, J.-P.: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, IPCC, Geneva, Switzerland, https://epic.awi.de/id/eprint/37530/, 2014.

Palinkas, C. M., Orton, P., Hummel, M. A., Nardin, W., Sutton-Grier, A. E., Harris, L., Gray, M., Li, M., Ball, D., Burks-Copes, K., Davlasheridze, M., De Schipper, M., George, D. A., Halsing, D., Maglio, C., Marrone, J., McKay, S. K., Nutters, H., Orff, K., Taal, M., Van Oudenhoven, A. P. E., Veatch, W., and Williams, T.: Innovations in Coastline Management With Natural and Nature-Based Features (NNBF): Lessons Learned From Three Case Studies, Frontiers in Built Environment, 8, https://doi.org/10.3389/fbuil.2022.814180, publisher: Frontiers, 2022.

Pan, Y., Birdsey, R. A., Phillips, O. L., Houghton, R. A., Fang, J., Kauppi, P. E., Keith, H., Kurz, W. A., Ito, A., Lewis, S. L., and others: The enduring world forest carbon sink, Nature, 631, 563–569, publisher: Nature Publishing Group UK London, 2024.

Papastefanou, P., Zang, C. S., Angelov, Z., De Castro, A. A., Jimenez, J. C., De Rezende, L. F. C., Ruscica, R. C., Sakschewski, B., Sörensson, A. A., Thonicke, K., and others: Recent extreme drought events in the Amazon rainforest: Assessment of different precipitation and evapotranspiration datasets and drought indicators, Biogeosciences, 19, 3843–3861, https://doi.org/10.5194/bg-19-3843-2022, 2022.

Parr, C. L., Te Beest, M., and Stevens, N.: Conflation of reforestation with restoration is widespread, Science, 383, 698–701, https://doi.org/10.1126/science.adj089, 2024.

Pascual, U., Balvanera, P., Anderson, C. B., Chaplin-Kramer, R., Christie, M., González-Jiménez, D., Martin, A., Raymond, C. M., Termansen, M., Vatn, A., Athayde, S., Baptiste, B., Barton, D. N., Jacobs, S., Kelemen, E., Kumar, R., Lazos, E., Mwampamba, T. H., Nakangu, B., O'Farrell, P., Subramanian, S. M., van Noordwijk, M., Ahn, S., Amaruzaman, S., Amin, A. M., Arias-Arévalo, P., Arroyo-Robles, G., Cantú-Fernández, M., Castro, A. J., Contreras, V., De Vos, A., Dendoncker, N., Engel, S., Eser, U., Faith, D. P., Filyushkina, A., Ghazi, H., Gómez-Baggethun, E., Gould, R. K., Guibrunet, L., Gundimeda, H., Hahn, T., Harmáčková, Z. V., Hernández-Blanco, M., Horcea-Milcu, A.-I., Huambachano, M., Wicher, N. L. H., Aydın, C. I., Islar, M., Koessler, A.-K., Kenter, J. O., Kosmus, M., Lee, H., Leimona, B., Lele, S., Lenzi, D., Lliso, B., Mannetti, L. M., Merçon, J., Monroy-Sais, A. S., Mukherjee, N., Muraca, B., Muradian, R., Murali, R., Nelson, S. H., Nemogá-Soto, G. R., Ngouhouo-Poufoun, J., Niamir, A., Nuesiri, E., Nyumba, T. O., Özkaynak, B., Palomo, I., Pandit, R., Pawłowska-Mainville, A., Porter-Bolland, L., Quaas, M., Rode, J., Rozzi, R., Sachdeva, S., Samakov, A., Schaafsma, M., Sitas, N., Ungar, P., Yiu, E., Yoshida, Y., and Zent, E.: Diverse values of nature for sustainability, Nature, 620, 813–823, https://doi.org/10.1038/s41586-023-06406-9, 2023.

Pausas, J. G. and Keeley, J. E.: A burning story: the role of fire in the history of life, BioScience, 59, 593–601, https://doi.org/10.1525/bio.2009.59.7.10, 2009.

Pendrill, F., Gardner, T. A., Meyfroidt, P., Persson, U. M., Adams, J., Azevedo, T., Bastos Lima, M. G., Baumann, M., Curtis, P. G., De Sy, V., Garrett, R., Godar, J., Goldman, E. D., Hansen, M. C., Heilmayr, R., Herold, M., Kuemmerle, T., Lathuillière, M. J., Ribeiro, V., Tyukavina, A., Weisse, M. J., and West, C.: Disentangling the numbers behind agriculture-driven tropical deforestation, Science, 377, eabm9267, https://doi.org/10.1126/science.abm9267, 2022.

Pereira, H. M., Rosa, I. M. D., Martins, I. S., Kim, H., Leadley, P., Popp, A., Vuuren, D. P. v., Hurtt, G., Anthoni, P., Arneth, A., Baisero, D., Chaplin-Kramer, R., Chini, L., Fulvio, F. D., Marco, M. D., Ferrier, S., Fujimori, S., Guerra, C. A., Harfoot, M., Harwood, T. D., Hasegawa, T., Haverd, V., Havlík, P., Hellweg, S., Hilbers, J. P., Hill, S. L. L., Hirata, A., Hoskins, A. J., Humpenöder, F., Janse, J. H., Jetz, W., Johnson, J. A., Krause, A., Leclère, D., Matsui, T., Meijer, J. R., Merow, C., Obsersteiner, M., Ohashi, H., Poulter, B., Purvis, A., Quesada, B., Rondinini, C., Schipper, A. M., Settele, J., Sharp, R., Stehfest, E., Strassburg, B. B. N., Takahashi, K., Talluto, M. V., Thuiller, W., Titeux, N., Visconti, P., Ware, C., Wolf, F., and Alkemade, R.: Global trends in biodiversity and ecosystem services from 1900 to 2050, https://doi.org/10.1101/2020.04.14.031716, 2020a.

Pereira, H. M., Martins, I. S., Rosa, I. M. D., Kim, H., Leadley, P., Popp, A., van Vuuren, D. P., Hurtt, G., Quoss, L., Arneth, A., Baisero, D., Bakkenes, M., Chaplin-Kramer, R., Chini, L., Di Marco, M., Ferrier, S., Fujimori, S., Guerra, C. A., Harfoot, M., Harwood, T. D., Hasegawa, T., Haverd, V., Havlík, P., Hellweg, S., Hilbers, J. P., Hill, S. L. L., Hirata, A., Hoskins, A. J., Humpenöder, F., Janse, J. H., Jetz, W., Johnson, J. A., Krause, A., Leclère, D., Matsui, T., Meijer, J. R., Merow, C., Obersteiner, M., Ohashi, H., De Palma, A., Poulter, B., Purvis, A., Quesada, B., Rondinini, C., Schipper, A. M., Settele, J., Sharp, R., Stehfest, E., Strassburg, B. B. N., Takahashi, K., Talluto, M. V., Thuiller, W., Titeux, N., Visconti, P., Ware, C., Wolf, F., and Alkemade, R.: Global trends and scenarios for terrestrial biodiversity and ecosystem services from 1900 to 2050, Science, 384, 458–465, https://doi.org/10.1126/science.adn3441, 2024.

Pereira, L. M., Davies, K. K., den Belder, E., Ferrier, S., Karlsson-Vinkhuyzen, S., Kim, H., Kuiper, J. J., Okayasu, S., Palomo, M. G., Pereira, H. M., Peterson, G., Sathyapalan, J., Schoolenberg, M., Alkemade, R., Carvalho Ribeiro, S., Greenaway, A., Hauck, J., King, N., Lazarova, T., Ravera, F., Chettri, N., Cheung, W. W. L., Hendriks, R. J. J., Kolomytsev, G., Leadley, P., Metzger, J.-P., Ninan, K. N., Pichs, R., Popp, A., Rondinini, C., Rosa, I., van Vuuren, D., and Lundquist, C. J.: Developing multiscale and integrative nature–people scenarios using the Nature Futures Framework, People and Nature, 2, 1172–1195, https://doi.org/10.1002/pan3.10146, 2020b.

Pereira, L. M., Gianelli, I., Achieng, T., Amon, D., Archibald, S., Arif, S., Castro, A., Chimbadzwa, T. P., Coetzer, K., Field, T.-L., Selomane, O., Sitas, N., Stevens, N., Villasante, S., Armani, M., Kimuyu, D. M., Adewumi, I. J., Lapola, D. M., Obura, D., Pinho, P., Roa-Clavijo, F., Rocha, J., and Sumaila, U. R.: Equity and justice should underpin the discourse on tipping points, Earth System Dynamics, 15, 341–366, https://doi.org/10.5194/esd-15-341-2024, 2023.

Perino, A., Pereira, H. M., Felipe-Lucia, M., Kim, H., Kühl, H. S., Marselle, M. R., Meya, J. N., Meyer, C., Navarro, L. M., van Klink, R., Albert, G., Barratt, C. D., Bruelheide, H., Cao, Y., Chamoin, A., Darbi, M., Dornelas, M., Eisenhauer, N., Essl, F., Farwig, N., Förster, J., Freyhof, J., Geschke, J., Gottschall, F., Guerra, C., Haase, P., Hickler, T., Jacob, U., Kastner, T., Korell, L., Kühn, I., Lehmann, G. U. C., Lenzner, B., Marques, A., Motivans Švara, E., Quintero, L. C., Pacheco, A., Popp, A., Rouet-Leduc, J., Schnabel, F., Siebert, J., Staude, I. R., Trogisch, S., Švara, V., Svenning, J.-C., Pe'er, G., Raab, K., Rakosy, D., Vandewalle, M., Werner, A. S., Wirth, C., Xu, H., Yu, D., Zinngrebe, Y., and Bonn, A.: Biodiversity post-2020: Closing the gap between global targets and national-level implementation, Conservation Letters, 15, e12 848, https://doi.org/10.1111/conl.12848, 2022.

Phillips, C. A., Rogers, B. M., Elder, M., Cooperdock, S., Moubarak, M., Randerson, J. T., and Frumhoff, P. C.: Escalating carbon emissions from North American boreal forest wildfires and the climate mitigation potential of fire management, Science advances, 8, eabl7161, https://doi.org/https://doi.org/10.1126/sciadv.abl7161, 2022.

Phillips, O. L., Aragão, L. E. O. C., Lewis, S. L., Fisher, J. B., Lloyd, J., López-González, G., Malhi, Y., Monteagudo, A., Peacock, J., Quesada, C. A., van der Heijden, G., Almeida, S., Amaral, I., Arroyo, L., Aymard, G., Baker, T. R., Bánki, O., Blanc, L., Bonal, D., Brando, P., Chave, J., de Oliveira, A. C. A., Cardozo, N. D., Czimczik, C. I., Feldpausch, T. R., Freitas, M. A., Gloor, E., Higuchi, N., Jiménez, E., Lloyd, G., Meir, P., Mendoza, C., Morel, A., Neill, D. A., Nepstad, D., Patiño, S., Peñuela, M. C., Prieto, A., Ramírez, F., Schwarz, M., Silva, J., Silveira, M., Thomas, A. S., Steege, H. t., Stropp, J., Vásquez, R., Zelazowski, P., Dávila, E. A., Andelman, S., Andrade, A., Chao, K.-J., Erwin, T., Di Fiore, A., C., E. H., Keeling, H., Killeen, T. J., Laurance, W. F., Cruz, A. P., Pitman, N. C. A., Vargas, P. N., Ramírez-Angulo, H., Rudas, A., Salamão, R., Silva, N., Terborgh, J., and Torres-Lezama, A.: Drought Sensitivity of the Amazon Rainforest, Science, 323, 1344–1347, https://doi.org/10.1126/science.1164033, 2009.

Pickering, J., Coolsaet, B., Dawson, N., Suiseeya, K. M., Inoue, C. Y. A., and Lim, M.: Rethinking and Upholding Justice and Equity in Transformative Biodiversity Governance, in: Transforming Biodiversity Governance, edited by Visseren-Hamakers, I. J. and Kok, M. T. J., pp. 155–178, Cambridge University Press, Cambridge, https://ueaeprints.uea.ac.uk/id/eprint/85334, 2022.

Pollock, L. J., O'connor, L. M., Mokany, K., Rosauer, D. F., Talluto, M. V., and Thuiller, W.: Protecting biodiversity (in all its complexity): new models and methods, Trends in Ecology & Evolution, 35, 1119–1128, 2020.

Poveda, G. and Mesa, O. J.: Feedbacks between Hydrological Processes in Tropical South America and Large-Scale Ocean–Atmospheric Phenomena, Journal of Climate, 10, 2690–2702, https://doi.org/10.1175/1520-0442(1997)010<2690:FBHPIT>2.0.CO;2, 1997.

Priyadarshana, T. S., Martin, E. A., Sirami, C., Woodcock, B. A., Goodale, E., Martínez-Núñez, C., Lee, M.-B., Pagani-Núñez, E., Raderschall, C. A., Brotons, L., and others: Crop and landscape heterogeneity increase biodiversity in agricultural landscapes: A global review and meta-analysis, Ecology Letters, 27, e14 412, https://doi.org/10.1111/ele.14412, 2024.

Pyšek, P., Hulme, P. E., Simberloff, D., Bacher, S., Blackburn, T. M., Carlton, J. T., Dawson, W., Essl, F., Foxcroft, L. C., Genovesi, P., Jeschke, J. M., Kühn, I., Liebhold, A. M., Mandrak, N. E., Meyerson, L. A., Pauchard, A., Pergl, J., Roy, H. E., Seebens, H., van Kleunen, M., Vilà, M., Wingfield, M. J., and Richardson, D. M.: Scientists' warning on invasive alien species, Biological Reviews, 95, 1511–1534, https://doi.org/10.1111/brv.12627, 2020.

Pörtner, H.-O., Roberts, D. C., Masson-Delmotte, V., Zhai, P., Tignor, M., Poloczanska, E., Weyer, N., and others: The ocean and cryosphere in a changing climate, IPCC special report on the ocean and cryosphere in a changing climate, 1155, 2019.

Pörtner, H.-O., Scholes, R. J., Agard, J., Archer, E., Arneth, A., Bai, X., Barnes, D., Burrows, M., Chan, L., Cheung, W. L. W., Diamond, S., Donatti, C., Duarte, C., Eisenhauer, N., Foden, W., Gasalla, M. A., Handa, C., Hickler, T., Hoegh-Guldberg, O., Ichii, K., Jacob, U., Insarov, G., Kiessling, W., Leadley, P., Leemans, R., Levin, L., Lim, M., Maharaj, S., Managi, S., Marquet, P. A., McElwee, P., Midgley, G., Oberdorff, T., Obura, D., Osman Elasha, B., Pandit, R., Pascual, U., Pires, A. P. F., Popp, A., Reyes-García, V., Sankaran, M., Settele, J., Shin, Y.-J., Sintayehu, D. W., Smith, P., Steiner, N., Strassburg, B., Sukumar, R., Trisos, C., Val, A. L., Wu, J., Aldrian, E., Parmesan, C., Pichs-Madruga, R., Roberts, D. C., Rogers, A. D., Díaz, S., Fischer, M., Hashimoto, S., Lavorel, S., Wu, N., and Ngo, H.: Scientific outcome of the IPBES-IPCC co-sponsored workshop on biodiversity and climate change, info:eu-repo/semantics/report, IPBES secretariat, Bonn, http://dx.doi.org/10.5281/zenodo.4659158, 2021a.

Pörtner, H.-O., Scholes, R. J., Agard, J., Leemans, R., Archer, E., Bai, X., Barnes, D., Burrows, M., Chan, L., Cheung, W., and others: IPBES-IPCC co-sponsored workshop report on biodiversity and climate change, Tech. rep., IPBES secretariat, Bonn, Germany, http://dx.doi.org/10.5281/zenodo.4659158, 2021b.

Pörtner, H.-O., Scholes, R., Arneth, A., Barnes, D., Burrows, M. T., Diamond, S., Duarte, C. M., Kiessling, W., Leadley, P., Managi, S., and others: Overcoming the coupled climate and biodiversity crises and their societal impacts, Science, 380, eabl4881, https://doi.org/10.1126/science.abl4881, 2023.

Raja, N. B., Dunne, E. M., Matiwane, A., Khan, T. M., Nätscher, P. S., Ghilardi, A. M., and Chattopadhyay, D.: Colonial history and global economics distort our understanding of deep-time biodiversity, Nature Ecology & Evolution, 6, 145–154, https://doi.org/10.1038/s41559-021-01608-8, publisher: Nature Publishing Group, 2022.

Rakotomalala, A. A. N. A., Ficiciyan, A. M., and Tscharntke, T.: Intercropping enhances beneficial arthropods and controls pests: A systematic review and meta-analysis, Agriculture, Ecosystems & Environment, 356, 108 617, https://doi.org/10.1016/j.agee.2023.108617, 2023.

Regos, A., Pais, S., Campos, J. C., and Lecina-Diaz, J.: Nature-based solutions to wildfires in rural landscapes of Southern Europe: let's be fire-smart!, International Journal of Wildland Fire, 32, 942–950, https://doi.org/10.1071/WF22094, 2023.

Ripple, W. J., Wolf, C., Newsome, T. M., Barnard, P., Moomaw, W. R., and 11, . S. S. F. . C. L. I. S. F. S.: World Scientists' Warning of a Climate Emergency, BioScience, 70, 8–100, https://www.jstor.org/stable/26891410, 2020.

Ripple, W. J., Wolf, C., Gregg, J. W., Rockström, J., Newsome, T. M., Law, B. E., Marques, L., Lenton, T. M., Xu, C., Huq, S., Simons, L., and King, S. D. A.: The 2023 state of the climate report: Entering uncharted territory, BioScience, 73, 841–850, https://doi.org/10.1093/biosci/biad080, 2023.

Robinson, A., Lehmann, J., Barriopedro, D., Rahmstorf, S., and Coumou, D.: Increasing heat and rainfall extremes now far outside the historical climate, npj Climate and Atmospheric Science, 4, 1–4, https://doi.org/10.1038/s41612-021-00202-w, 2021.

Rockström, J., Gaffney, O., Rogelj, J., Meinshausen, M., Nakicenovic, N., and Schellnhuber, H. J.: A roadmap for rapid decarbonization, Science, 355, 1269–1271, https://doi.org/10.1126/science.aah3443, 2017.

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., and others: Safe and just Earth system boundaries, Nature, 619, 102–111, https://doi.org/10.1038/s41586-023-06083-8, 2023.

Roebroek, C. T. J., Duveiller, G., Seneviratne, S. I., Davin, E. L., and Cescatti, A.: Releasing global forests from human management: How much more carbon could be stored?, Science, 380, 749–753, https://doi.org/10.1126/science.add5878, 2023.

Rounsevell, M. D., Harfoot, M., Harrison, P. A., Newbold, T., Gregory, R. D., and Mace, G. M.: A biodiversity target based on species extinctions, Science, 368, 1193–1195, https://doi.org/10.1126/science.aba6592, 2020.

Roy, H. E., Pauchard, A., Stoett, P., and Renard Truong, T.: IPBES Invasive Alien Species Assessment: Full report, Tech. rep., Zenodo, https://doi.org/10.5281/zenodo.11629357, 2024.

Saintilan, N., Horton, B., Törnqvist, T. E., Ashe, E. L., Khan, N. S., Schuerch, M., Perry, C., Kopp, R. E., Garner, G. G., Murray, N., Rogers, K., Albert, S., Kelleway, J., Shaw, T. A., Woodroffe, C. D., Lovelock, C. E., Goddard, M. M., Hutley, L. B., Kovalenko, K., Feher, L., and Guntenspergen, G.: Widespread retreat of coastal habitat is likely at warming levels above 1.5 °C, Nature, 621, 112–119, https://doi.org/10.1038/s41586-023-06448-z, 2023.

San-Miguel-Ayanz, J., Moreno, J. M., and Camia, A.: Analysis of large fires in European Mediterranean landscapes: Lessons learned and perspectives, Forest Ecology and Management, 294, 11–22, https://doi.org/10.1016/j.foreco.2012.10.050, 2013.

Sanchez, G. M., Grone, M., and Apodaca, A.: Indigenous stewardship of coastal resources in native California, Frontiers in Earth Science, 11, https://doi.org/10.3389/feart.2023.1064197, 2023.

Schlesier, H., Schäfer, M., and Desing, H.: Measuring the Doughnut: A good life for all is possible within planetary boundaries, Journal of Cleaner Production, 448, 141 447, https://doi.org/10.1016/j.jclepro.2024.141447, 2024.

Scholten, R. C., Jandt, R., Miller, E. A., Rogers, B. M., and Veraverbeke, S.: Overwintering fires in boreal forests, Nature, 593, 399–404, https://doi.org/10.1038/s41586-021-03437-y, 2021.

Seddon, N.: Harnessing the potential of nature-based solutions for mitigating and adapting to climate change, Science, 376, 1410–1416, https://doi.org/10.1126/science.abn9668, 2022.

Seebens, H., Niamir, A., Essl, F., Garnett, S. T., Kumagai, J. A., Molnár, Z., Saeedi, H., and Meyerson, L. A.: Biological invasions on Indigenous peoples' lands, Nature Sustainability, 7, 737–746, https://doi.org/10.1038/s41893-024-01361-3, 2024.

Shah, K. K., Modi, B., Pandey, H. P., Subedi, A., Aryal, G., Pandey, M., and Shrestha, J.: Diversified Crop Rotation: An Approach for Sustainable Agriculture Production, Advances in Agriculture, 2021, 8924 087, https://doi.org/10.1155/2021/8924087, 2021.

Skaalsveen, K., Ingram, J., and Clarke, L. E.: The effect of no-till farming on the soil functions of water purification and retention in north-western Europe: A literature review, Soil and Tillage Research, 189, 98–109, https://doi.org/10.1016/j.still.2019.01.004, 2019.

Smith, C., Baker, J. C. A., and Spracklen, D. V.: Tropical deforestation causes large reductions in observed precipitation, Nature, 615, 270–275, https://doi.org/10.1038/s41586-022-05690-1, 2023.

Song, S., Ding, Y., Li, W., Meng, Y., Zhou, J., Gou, R., Zhang, C., Ye, S., Saintilan, N., Krauss, K. W., Crooks, S., Lv, S., and Lin, G.: Mangrove reforestation provides greater blue carbon benefit than afforestation for mitigating global climate change, Nature Communications, 14, 756, https://doi.org/10.1038/s41467-023-36477-1, 2023.

Sorí, R., Nieto, R., Vicente-Serrano, S. M., Drumond, A., and Gimeno, L.: A Lagrangian perspective of the hydrological cycle in the Congo River basin, Earth System Dynamics, 8, 653–675, https://doi.org/10.5194/esd-8-653-2017, 2017.

Spracklen, D. V. and Garcia-Carreras, L.: The impact of Amazonian deforestation on Amazon basin rainfall, Geophysical Research Letters, 42, 9546–9552, https://doi.org/10.1002/2015GL066063, 2015.

Spracklen, D. V., Arnold, S. R., and Taylor, C.: Observations of increased tropical rainfall preceded by air passage over forests, Nature, 489, 282–285, https://doi.org/10.1038/nature11390, 2012.

Staal, A., Tuinenburg, O. A., Bosmans, J. H. C., Holmgren, M., van Nes, E. H., Scheffer, M., Zemp, D. C., and Dekker, S. C.: Forest-rainfall cascades buffer against drought across the Amazon, Nature Climate Change, 8, 539–543, https://doi.org/10.1038/s41558-018-0177-y, 2018.

Staal, A., Flores, B. M., Aguiar, A. P. D., Bosmans, J. H., Fetzer, I., and Tuinenburg, O. A.: Feedback between drought and deforestation in the Amazon, Environmental Research Letters, 15, 044 024, https://doi.org/10.1088/1748-9326/ab738e, 2020.

Staal, A., Koren, G., Tejada, G., and Gatti, L. V.: Moisture origins of the Amazon carbon source region, Environmental Research Letters, 18, 044 027, https://doi.org/10.1088/1748-9326/acc676, 2023.

Steffen, W., Rockström, J., Richardson, K., Lenton, T. M., Folke, C., Liverman, D., Summerhayes, C. P., Barnosky, A. D., Cornell, S. E., Crucifix, M., Donges, J. F., Fetzer, I., Lade, S. J., Scheffer, M., Winkelmann, R., and Schellnhuber, H. J.: Trajectories of the Earth System in the Anthropocene, Proceedings of the National Academy of Sciences, 115, 8252–8259, https://doi.org/10.1073/pnas.1810141115, 2018.

Sterner, T. and Persson, U. M.: An Even Sterner Review: Introducing Relative Prices into the Discounting Debate, Review of Environmental Economics and Policy, 2, 61–76, https://doi.org/10.1093/reep/rem024, 2008.

Stubbins, A., Law, K. L., Muñoz, S. E., Bianchi, T. S., and Zhu, L.: Plastics in the Earth system, Science, 373, 51–55, https://doi.org/10.1126/science.abb0354, 2021.

Sullivan, S.: Elephant in the room? Problematising 'new'(neoliberal) biodiversity conservation, in: Forum for Development Studies, vol. 33, pp. 105–135, Taylor & Francis, https://doi.org/10.1080/08039410.2006.9666337, 2006.

Sunkur, R., Kantamaneni, K., Bokhoree, C., and Ravan, S.: Mangroves' role in supporting ecosystem-based techniques to reduce disaster risk and adapt to climate change: A review, Journal of Sea Research, 196, 102 449, https://doi.org/10.1016/j.seares.2023.102449, 2023.

Sánchez-Bayo, F. and Wyckhuys, K. A.: Worldwide decline of the entomofauna: A review of its drivers, Biological conservation, 232, 8–27, https://doi.org/10.1016/j.biocon.2019.01.020, 2019.

Tao, S., Chave, J., Frison, P.-L., Le Toan, T., Ciais, P., Fang, J., Wigneron, J.-P., Santoro, M., Yang, H., Li, X., and others: Increasing and widespread vulnerability of intact tropical rainforests to repeated droughts, Proceedings of the National Academy of Sciences, 119, e2116626 119, 2022.

Tedesco, A. M., Brancalion, P. H. S., Hepburn, M. L. H., Walji, K., Wilson, K. A., Possingham, H. P., Dean, A. J., Nugent, N., Elias-Trostmann, K., Perez-Hammerle, K.-V., and Rhodes, J. R.: The role of incentive mechanisms in promoting forest restoration, Philosophical Transactions of the Royal Society B: Biological Sciences, 378, 20210 088, https://doi.org/10.1098/rstb.2021.0088, 2022.

Teixeira, J. C. M., Burton, C., Kelly, D. I., Folberth, G. A., O'Connor, F. M., Betts, R. A., and Voulgarakis, A.: Representing socio-economic factors in the INFERNO global fire model using the Human Development Index, Biogeosciences Discussions, pp. 1–27, https://doi.org/10.5194/bg-2023-136, 2023.

Thomas, R., Davies, J., King, C., Kuse, J., Schauer, M., Bisom, N., Tsegai, D., and Madani, K.: Economics of Drought: Investing in Nature-Based Solutions for Drought Resilience – Proaction Pays. A joint report by UNCCD, ELD Initiative and UNU-INWEH, Tech. rep., UNCCD, ELD Initiative and UNU-INWEH, Bonn, Germany; Toronto, Canada., 2024.

TNDF: Recommendations of the Taskforce on Nature-related Financial Disclosures., https://tnfd.global/publication/recommendations-of-the-taskforce-on-nature-related-financial-disclosures/, 2023.

Torchio, G. M., Cimon-Morin, J., Mendes, P., Goyette, J.-O., Schwantes, A. M., Arias-Patino, M., Bennett, E. M., Destrempes, C., Pellerin, S., and Poulin, M.: From marginal croplands to natural habitats: A methodological framework for assessing the restoration potential to enhance wild-bee pollination in agricultural landscapes, Landscape Ecology, 39, 194, https://doi.org/10.1007/s10980-024-01993-y, 2024.

Toth, L. T., Storlazzi, C. D., Kuffner, I. B., Quataert, E., Reyns, J., McCall, R., Stathakopoulos, A., Hillis-Starr, Z., Holloway, N. H., Ewen, K. A., Pollock, C. G., Code, T., and Aronson, R. B.: The potential for coral reef restoration to mitigate coastal flooding as sea levels rise, Nature Communications, 14, 2313, https://doi.org/10.1038/s41467-023-37858-2, 2023.

Trégarot, E., D'Olivo, J. P., Botelho, A. Z., Cabrito, A., Cardoso, G. O., Casal, G., Cornet, C. C., Cragg, S. M., Degia, A. K., Fredriksen, S., Furlan, E., Heiss, G., Kersting, D. K., Maréchal, J.-P., Meesters, E., O'Leary, B. C., Pérez, G., Seijo-Núñez, C., Simide, R., van der Geest, M., and de Juan, S.: Effects of climate change on marine coastal ecosystems – A review to guide research and management, Biological Conservation, 289, 110 394, https://doi.org/10.1016/j.biocon.2023.110394, 2024.

Tscharntke, T., Batáry, P., and Grass, I.: Mixing on- and off-field measures for biodiversity conservation, Trends in Ecology & Evolution, 0, https://doi.org/10.1016/j.tree.2024.04.003, 2024.

Tuinenburg, O. A., Theeuwen, J. J. E., and Staal, A.: High-resolution global atmospheric moisture connections from evaporation to precipitation, Earth System Science Data, 12, 3177–3188, https://doi.org/10.5194/essd-12-3177-2020, 2020.

Turetsky, M. R., Benscoter, B., Page, S., Rein, G., van der Werf, G. R., and Watts, A.: Global vulnerability of peatlands to fire and carbon loss, Nature Geoscience, 8, 11–14, https://doi.org/10.1038/ngeo2325, 2015.

UNCCD: The Great Green Wall: Hope for the Sahara and the Sahel, https://www.unccd.int/resources/publications/great-green-wall-hope-sahara-and-sahel, 2016.

UNEP: Emissions Gap Report 2022: The Closing Window. Climate Crisis Calls for Rapid Transformation of Societies, UN, 2022.

UNFCCC: The Paris Agreement, in: The Paris Agreement, Paris, https://unfccc.int/documents/184656, 2018.

van der Ent, R. J., Savenije, H. H. G., Schaefli, B., and Steele-Dunne, S. C.: Origin and fate of atmospheric moisture over continents, Water Resources Research, 46, https://doi.org/https://doi.org/10.1029/2010WR009127, 2010.

Veldman, J. W., Overbeck, G. E., Negreiros, D., Mahy, G., Le Stradic, S., Fernandes, G. W., Durigan, G., Buisson, E., Putz, F. E., and Bond, W. J.: Where tree planting and forest expansion are bad for biodiversity and ecosystem services, BioScience, 65, 1011–1018, https://doi.org/10.1093/biosci/biv118, 2015.

Vikström, H., Davidsson, S., and Höök, M.: Lithium availability and future production outlooks, Applied Energy, 110, 252–266, https://doi.org/10.1016/j.apenergy.2013.04.005, 2013.

Wakwella, A., Wenger, A., Jenkins, A., Lamb, J., Kuempel, C. D., Claar, D., Corbin, C., Falinski, K., Rivera, A., Grantham, H. S., and Jupiter, S. D.: Integrated watershed management solutions for healthy coastal ecosystems and people, Cambridge Prisms: Coastal Futures, 1, e27, https://doi.org/10.1017/cft.2023.15, 2023.

Wang, Z., Wang, Z., Zou, Z., Chen, X., Wu, H., Wang, W., Su, H., Li, F., Xu, W., Liu, Z., and Zhu, J.: Severe Global Environmental Issues Caused by Canada's Record-Breaking Wildfires in 2023, Advances in Atmospheric Sciences, 41, 565–571, https://doi.org/10.1007/s00376-023-3241-0, 2024.

Watson, J. E., Venter, O., Lee, J., Jones, K. R., Robinson, J. G., Possingham, H. P., and Allan, J. R.: Protect the last of the wild, https://doi.org/10.1038/d41586-018-07183-6, 2018.

Watson, R., Baste, I., Larigauderie, A., Leadley, P., Pascual, U., Baptiste, B., Demissew, S., Dziba, L., Erpul, G., Fazel, A., and others: Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, IPBES Secretariat: Bonn, Germany, pp. 22–47, 2019.

Watts, M.: Political ecology, A companion to economic geography, pp. 257–274, 2017.

Webb, A. E., Enochs, I. C., van Hooidonk, R., van Westen, R. M., Besemer, N., Kolodziej, G., Viehman, T. S., and Manzello, D. P.: Restoration and coral adaptation delay, but do not prevent, climate-driven reef framework erosion of an inshore site in the Florida Keys, Scientific Reports, 13, 258, https://doi.org/10.1038/s41598-022-26930-4, 2023.

Wessely, J., Essl, F., Fiedler, K., Gattringer, A., Hülber, B., Ignateva, O., Moser, D., Rammer, W., Dullinger, S., and Seidl, R.: A climate-induced tree species bottleneck for forest management in Europe, Nature Ecology & Evolution, 8, 1109–1117, https://doi.org/10.1038/s41559-024-02406-8, publisher: Nature Publishing Group, 2024.

Wiedmann, T. and Lenzen, M.: Environmental and social footprints of international trade, Nature Geoscience, 11, 314–321, https://doi.org/10.1038/s41561-018-0113-9, 2018.

Wiedmann, T., Lenzen, M., Keyßer, L. T., and Steinberger, J. K.: Scientists' warning on affluence, Nature Communications, 11, 3107, https://doi.org/10.1038/s41467-020-16941-y, 2020.

Willmer, J. N. G., Püttker, T., and Prevedello, J. A.: Global impacts of edge effects on species richness, Biological Conservation, 272, 109 654, https://doi.org/10.1016/j.biocon.2022.109654, 2022.

Wuerthner, G., Crist, E., and Butler, T.: Protecting the Wild: Parks and Wilderness, the Foundation for Conservation, Island Press, 2015.

WWF: Living Planet Report 2024 – A System in Peril., WWF, Gland, Switzerland, 2024.

Xu, R., Ye, T., Yue, X., Yang, Z., Yu, W., Zhang, Y., Bell, M. L., Morawska, L., Yu, P., Zhang, Y., Wu, Y., Liu, Y., Johnston, F., Lei, Y., Abramson, M. J., Guo, Y., and Li, S.: Global population exposure to landscape fire air pollution from 2000 to 2019, Nature, 621, 521–529, https://doi.org/10.1038/s41586-023-06398-6, 2023.

Yamano, H., Kayanne, H., Yamaguchi, T., Kuwahara, Y., Yokoki, H., Shimazaki, H., and Chikamori, M.: Atoll island vulnerability to flooding and inundation revealed by historical reconstruction: Fongafale Islet, Funafuti Atoll, Tuvalu, Global and Planetary Change, 57, 407–416, https://doi.org/10.1016/j.gloplacha.2007.02.007, 2007.

Yu, M., Zhang, S., Ning, H., Li, Z., and Zhang, K.: Assessing the 2023 Canadian wildfire smoke impact in Northeastern US: Air quality, exposure and environmental justice, Science of The Total Environment, 926, 171 853, https://doi.org/10.1016/j.scitotenv.2024.171853, 2024.

Yu, Z., Chen, X., Zhou, G., Agathokleous, E., Li, L., Liu, Z., Wu, J., Zhou, P., Xue, M., Chen, Y., Yan, W., Liu, L., Shi, T., and Zhao, X.: Natural forest growth and human induced ecosystem disturbance influence water yield in forests, Communications Earth & Environment, 3, 1–8, https://doi.org/10.1038/s43247-022-00483-w, 2022.

Zemp, D., Schleussner, C.-F., Barbosa, H., Van Der Ent, R., Donges, J. F., Heinke, J., Sampaio, G., and Rammig, A.: On the importance of cascading moisture recycling in South America, Atmospheric Chemistry and Physics, 14, 13 337–13 359, 2014.

Zemp, D. C., Schleussner, C.-F., Barbosa, H. d. M. J., and Rammig, A.: Deforestation effects on Amazon forest resilience, Geophysical Research Letters, 44, 6182–6190, https://doi.org/10.5194/acp-14-13337-2014, 2017.

Zhang, M. and Wei, X.: Deforestation, forestation, and water supply, Science, 371, 990–991, https://doi.org/10.1126/science.abe7821, 2021.

Zhang, M., Liu, N., Harper, R., Li, Q., Liu, K., Wei, X., Ning, D., Hou, Y., and Liu, S.: A global review on hydrological responses to forest change across multiple spatial scales: Importance of scale, climate, forest type and hydrological regime, Journal of Hydrology, 546, 44–59, https://doi.org/10.1016/j.jhydrol.2016.12.040, 2017.

Zhao, C., Liu, B., Piao, S., Wang, X., Lobell, D. B., Huang, Y., Huang, M., Yao, Y., Bassu, S., Ciais, P., Durand, J.-L., Elliott, J., Ewert, F., Janssens, I. A., Li, T., Lin, E., Liu, Q., Martre, P., Müller, C., Peng, S., Peñuelas, J., Ruane, A. C., Wallach, D., Wang, T., Wu, D., Liu, Z., Zhu, Y., Zhu, Z., and Asseng, S.: Temperature increase reduces global yields of major crops in four independent estimates, Proceedings of the National Academy of Sciences, 114, 9326–9331, https://doi.org/10.1073/pnas.1701762114, 2017.

Zheng, B., Ciais, P., Chevallier, F., Yang, H., Canadell, J. G., Chen, Y., van der Velde, I. R., Aben, I., Chuvieco, E., Davis, S. J., and others: Record-high CO2 emissions from boreal fires in 2021, Science, 379, 912–917, https://doi.org/10.1126/science.ade0805, 2023.

Zickfeld, K., MacIsaac, A. J., Canadell, J. G., Fuss, S., Jackson, R. B., Jones, C. D., Lohila, A., Matthews, H. D., Peters, G. P., Rogelj, J., and Zaehle, S.: Net-zero approaches must consider Earth system impacts to achieve climate goals, Nature Climate Change, 13, 1298–1305, https://doi.org/10.1038/s41558-023-01862-7, 2023.

Zomer, R. J., Bossio, D. A., Trabucco, A., Noordwijk, M. V., and Xu, J.: Global carbon sequestration potential of agroforestry and increased tree cover on agricultural land, Circular Agricultural Systems, 2, 1–10, https://doi.org/10.48130/CAS-2022-0003, 2022.

Appendix A: Questionnaire

A1 Disclaimer:

We welcome contributions from all active researchers in all disciplines working on issues related to ecosystems and human interactions with these systems worldwide. Please tell us what you think are the 1-3 most important discoveries or advances in your field of research since 1 January 2022, and the key articles and reports that highlight these findings. In order to cover a specific topic, the editorial team requests at least two articles published after 1 January 2022. Each response must meet the following criteria:

– sufficient evidence from peer-reviewed publications in the last two years;

– no ongoing critical debate on the issue;

– relevance to international negotiations.

A2 Questions

- What is an important recent advance in biosphere research related to climate change and other anthropogenic stressors? Please add up to 5 publications published since 1-1-2022 that support your claim. (if possible weblinks or library references)
- What is an important recent advance in biosphere research related to adaptation and mitigation potentials? Please add up to 5 publications published since 1-1-2022 that support your claim. (if possible weblinks or library references)
- What is an important recent advance in biosphere research related to the identification of efficient policy making and economics concepts? Please add up to 5 publications published since 1-1-2022 that support your claim. (if possible weblinks or library references)