Received: 25 September 2020 | Revised: 24 December 2020 | Accepted: 27 December 2020

DOI: 10.1111/gcb.15513

GCB REVIEWS

Global Change Biology WILEY

Getting the message right on nature-based solutions to climate change

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Funding information

Natural Environment Research Council, Grant/Award Number: NE/R002649/1; University of Oxford; Belmont Forum; NORFACE Joint Research Programme on Transformations to Sustainability, Grant/Award Number: 730211

Abstract

Nature-based solutions (NbS)—solutions to societal challenges that involve working with nature—have recently gained popularity as an integrated approach that can address climate change and biodiversity loss, while supporting sustainable development. Although well-designed NbS can deliver multiple benefits for people and nature, much of the recent limelight has been on tree planting for carbon sequestration. There are serious concerns that this is distracting from the need to rapidly phase out use of fossil fuels and protect existing intact ecosystems. There are also concerns that the expansion of forestry framed as a climate change mitigation solution is coming at the cost of carbon rich and biodiverse native ecosystems and local resource rights. Here, we discuss the promise and pitfalls of the NbS framing and its current political traction, and we present recommendations on how to get the message right. We urge policymakers, practitioners and researchers to consider the synergies and trade-offs associated with NbS and to follow four guiding principles to enable NbS to provide sustainable benefits to society: (1) NbS are not a substitute for the rapid phase out of fossil fuels; (2) NbS involve a wide range of ecosystems on land and in the sea, not just forests; (3) NbS are implemented with the full engagement and consent of Indigenous Peoples and local communities in a way that respects their cultural and ecological rights; and (4) NbS should be explicitly designed to provide measurable benefits for biodiversity. Only by following these guidelines will we design robust and resilient NbS that address the urgent challenges of climate change and biodiversity loss, sustaining nature and people together, now and into the future.

KEYWORDS

biodiversity, climate change adaptation, climate change mitigation, policy, sustainable development

1 | INTRODUCTION

The past two years have seen the publication of several major global synthesis reports that collectively paint a bleak picture of the current state of the climate and biosphere. Not only are we failing to stabilize the climate (IPCC, 2014, 2018) or stem the tide of biodiversity loss on land (IPBES, 2019; NYDF Assessment Partners, 2019; WWF, 2020a) and in the sea (IPCC, 2019a), but these failures are increasing poverty and

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inequality across the globe and are severely undermining the development gains of the 20th Century (IPBES, 2019; WEF, 2020a, 2020b). There is a growing realization that these challenges are interlinked and cannot be addressed independently (IPCC, 2019b; Turney et al., 2020). As evidence builds that the natural systems on which we depend are deteriorating beyond a point of no return (IPCC, 2018; Rockström et al., 2009; Steffen et al., 2015), it is clear that larger scale and more coherent approaches to tackling global challenges are needed.

Nature-based solutions (NbS)—solutions to societal challenges that involve working with nature—have recently gained popularity as an integrated approach that could address the twin crises of climate change and biodiversity loss (Seddon, Chausson, et al., 2020), while supporting a wide range of sustainable development goals (Gómez Martín et al., 2020; Maes et al., 2019). NbS are actions that are broadly categorized as the protection, restoration or management of natural and semi-natural ecosystems, sustainable management of working lands and aquatic systems, or the creation of novel ecosystems (Figure 1). Although more research is needed, a rapidly growing evidence base (Chausson et al., 2020; Hanson et al., 2020) demonstrates that well-designed NbS can deliver multiple benefits (Seddon, Chausson, et al., 2020). For example, protecting and restoring habitats along shorelines or in upper catchments can contribute to climate change adaptation by protecting communities and infrastructure from flooding and erosion, at the same time as increasing carbon sequestration and protecting biodiversity (Smith et al., 2017). Meanwhile, increasing green space and planting trees in urban areas can help with cooling and flood abatement while mitigating air pollution, providing recreation and health benefits and sequestering carbon (Alves et al., 2019; Brink et al., 2016; Figure 1).

The simple logic of 'working with and enhancing nature to help address societal challenges' (Seddon, Chausson, et al., 2020; Seddon

FIGURE 1 Conceptual diagram of nature-based solutions. Nature-based solutions (NbS) involve the protection, restoration or management of natural and semi-natural ecosystems; the sustainable management of aquatic systems and working lands such as croplands or timberlands; or the creation of novel ecosystems in and around cities or across the wider landscape. They are actions that are underpinned by biodiversity (Section 3.1) and are designed and implemented with the full engagement and consent of Indigenous Peoples and local communities (Section 3.2). People and nature, together (yellow circle), co-produce a variety of outcomes (ecosystem services or Nature's Contributions to People, blue band) which benefit society; these benefits can, in turn, support ecosystem health (blue arrows). While the ultimate goal of NbS is to support sustainable development, including human health and wellbeing, the ecosystems that provide NbS must be healthy, functional and biodiverse if such benefits are to be provided in the long term (Section 3.1). Hence, to qualify as an NbS, an action must sustainably provide one or more benefits for people (such as reducing flood risk or storing carbon) while causing no loss of biodiversity or ecological integrity (or preferably a gain) compared to the pre-intervention state. Although actions with only one societal benefit could be classified as NbS, an intervention in nature usually has multiple interlinked effects on the climate and the social-ecological system. By identifying all of these effects, interventions can be designed to build synergies and to be resilient to future climate and socio-economic change

TABLE 1 Definitions of nature-based solutions and commonly used terms and approaches that fall under the umbrella of NbS, as well as key concepts associated with NbS. This is not an exhaustive list

Term (acronym)	Definition	References
Nature-based solutions (NbS)	Actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human wellbeing and biodiversity benefits.	Cohen-Shacham et al. (2019); IUCN (2012)
	Nature-based solutions aim to help societies address a variety of environmental, social and economic challenges in sustainable ways. They are actions inspired by, supported by or copied from nature; both using and enhancing existing solutions to challenges, as well as exploring more novel solutions, for example, mimicking how non-human organisms and communities cope with environmental extremes.	European Commission (2015)
Terms encompassed by nature-based solutions		
Ecological engineering	The design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both.	Mitsch and Jørgensen (2003); Odum (1962)
Ecosystem-based adaptation (EbA)	The use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change.	CBD (2009)
Ecosystem-based disaster risk reduction (eco-DRR)	The sustainable management, conservation and restoration of ecosystems to reduce disaster risk, with the aim of achieving sustainable and resilient development.	Estralla and Saalismaa (2013); PEDDR (2010)
Green/blue infrastructure (GI/GBI/BI)	A strategically planned and managed, spatially interconnected network of multi-functional natural, semi-natural and man-made green and blue features including agricultural land, green corridors, urban parks, forest reserves, wetlands, rivers, coastal and other aquatic ecosystems.	European Commission (2013)
	An integrated network of natural and semi-natural areas and features, such as urban green spaces, greenways, parks, rain gardens, greenways, urban forestry, urban agriculture, green roofs and walls, etc.	De la Sota et al. (2019)
Integrated land management (ILM), Sustainable land management (SLM), Catchment management and the Ecosystem approach	Various approaches to managing whole landscapes sustainably, with participation by all stakeholders.	CBD (2000); Reed et al. (2017); Rollason et al. (2018); Thomas et al. (2018)
Agroforestry, including silvo-arable and silvo-pasture	The practice of planting trees on farmland, including as rows between crops, or as shelter for livestock.	Torralba et al. (2016)
Agro-ecology, conservation agriculture and organic agriculture	Various approaches to sustainable agriculture that aim to protect soil health.	Warren et al. (2008)
Forest and landscape restoration (FLR)	A process that aims to regain ecological integrity and enhance human wellbeing in a deforested or degraded forest landscape.	Maginnis and Jackson (2012)
Reduced emissions from deforestation and degradation+ (REDD+)	Reducing Emissions from Deforestation and forest Degradation, and fostering conservation, sustainable management of forests, and enhancement of forest carbon stocks in developing countries.	REDD+ 'rulebook', also known as the Warsaw Framework for REDD (UNFCCC, 2016); Paris Agreement (Article 5); (UNFCCC, 2015)
Natural climate solutions (NCS) or Nature-based Climate Solutions (NbCS)	Conservation and management actions that reduce greenhouse gas (GHG) emissions from ecosystems and harness their potential to store carbon.	Griscom et al. (2017)
Managed Realignment	Breaching existing coastal defences to create wetland areas for sustainable flood risk management with added environmental benefits.	Esteves and Thomas (2014)
Key concepts associated with nature-based solutions		
Blue Carbon	Organic carbon that is captured and stored by the oceans and coastal ecosystems, particularly by vegetated coastal ecosystems: seagrass meadows, tidal marshes and mangrove forests.	Macreadie et al. (2019)
Natural capital	Elements of nature that directly or indirectly produce value to people, including ecosystems, species, freshwater, land, minerals, the air and oceans, as well as natural processes and functions.	Janssen et al. (2020); NCC (2014)

(Continues)

TABLE 1 (Continued)

Term (acronym)	Definition	References
Ecosystem services (ES)	The benefits provided by ecosystems that contribute to human wellbeing.	Millennium Ecosystem Assessment (2005)
Nature's contributions to people (NCP)	All the positive contributions, or benefits, and occasionally negative contributions, losses or detriments that people obtain from nature.	Díaz et al. (2018)
Nature's contribution to adaptation (NCA)—formerly referred to as adaptation services	Properties of ecosystems that provide options for future livelihoods and adaptation to transformative change.	Colloff et al. (2020)

et al., 2019) has facilitated understanding and engagement across diverse sectors while the breadth of the concept has drawn together disparate communities of researchers, policymakers and practitioners across climate change, biodiversity and development (Cohen-Shacham et al., 2019; van Ham & Klimmek, 2017). In uniting nature-based approaches within a single framework (Table 1), and enabling a flexible, integrated approach to tackling different challenges, NbS can—if properly designed and implemented—enable synergies and minimize trade-offs between actions to achieve different goals. This has encouraged extensive uptake of the concept by governments (Table 2) and the private sector (Table 3; Cohen-Shacham et al., 2019; Nesshöver et al., 2017). NbS have been highlighted in recent global assessment reports conducted by bodies such as the Intergovernmental Panel on Climate Change (IPCC) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES; IPBES, 2018; IPCC, 2019a, 2019b); and are the focus of a growing number of major new programmes being implemented by governmental and non-governmental organizations, as well as private sector institutions (Seymour, 2020).

Although the simplicity and breadth of the NbS concept is a strength, it has also led to confusion. Much work has been done to improve the conceptualization of NbS (Eggermont et al., 2015), including recent development of a Global Standard for NbS by the International Union for the Conservation of Nature (IUCN; Cohen-Shacham et al., 2019; IUCN, 2020). Nonetheless, there is still uncertainty as to what ‘counts’ as an NbS and the extent to which NbS represent a departure from existing concepts and practices. In the context of climate change, concerns have been raised that NbS are being used to excuse business-as-usual consumption of fossil fuels (Anderson et al., 2019; Edwards, 2020); that there is an over-emphasis on tree planting as a ‘silver-bullet’ solution to climate change (Holl & Brancalion, 2020; Seymour, 2020) and that this is distracting from the urgent need to protect and connect a wide range of intact ecosystems across landscapes and seascapes (Solan et al., 2020; Watson et al., 2018). These issues arise partly from uncertainties in the underlying science, such as the limited set of contexts in which the broader benefits of NbS have been demonstrated (Chausson et al., 2020). They also arise as a result of miscommunications about the mitigation potential of working with nature, such as the recent meme that NbS can provide ‘30% of the climate solution’. There are also concerns that where rights are weak, especially around land tenure, NbS may be implemented in the absence of community consent or cause adverse social consequences. Such rights infringements can impede the success and sustainability of interventions (Ramprasad et al., 2020; Scheidel & Work, 2018; Vidal, 2008).

As public and private climate finance is increasingly directed towards NbS, it is vital to ensure that the concept is not misappropriated, co-opted or corrupted. Here, we discuss the origins and definitions of the NbS concept, show how and why NbS have gained popularity in recent years, summarize the promise and pitfalls of the NbS framing, and present guidelines on how to get the message right on what constitutes successful, sustainable NbS.

2 | ORIGINS AND DEFINITIONS OF NATURE-BASED SOLUTIONS

How NbS have been framed, identified and implemented has evolved over time. Local societies have been working with nature to cope with the impacts of natural disasters and climate variability for millennia (Berkes et al., 2000; Ruiz-Mallén et al., 2013). For example, there is a long documented history of interventions such as the restoration of mangroves to boost local livelihoods or provide flood protection (Kairo et al., 2001). It is only in recent years that such practices have been given scientific names (see Table 1 for examples) and, even more recently, classed as NbS. Through the establishment and recognition of the NbS concept, global interest in these types of practices has grown rapidly and NbS has moved up political agendas at municipal, national and international levels (Seddon, Chausson, et al., 2020).

The first publication to focus on NbS was a report by the World Bank in 2008 detailing the climate change mitigation and adaptation benefits of the Bank's investments in biodiversity conservation (Mackinnon et al., 2008). NbS were then adopted by the IUCN which promoted them ‘as a way to mitigate and adapt to climate change, secure water, food and energy supplies, reduce poverty and drive economic growth’ in a position paper for the United Nations Framework Convention on Climate Change (UNFCCC) 15th Conference of the Parties (IUCN, 2009). The IUCN went on to make NbS a major pillar of its 2013–2016 Program (IUCN, 2012), consolidating and building on its work on REDD+ (reduced emissions from deforestation and forest degradation) and ecosystem-based adaptation (EbA). Since then, the concept has been adopted by the European Commission

TABLE 2 Examples of major tree-planting initiatives

Name	Organizers/funders	Targets and methods
Global initiatives		
Bonn Challenge	Launched by IUCN and German Government in 2011. National governments work with stakeholders to develop strategies.	Committed to 350 Mha FLR by 2030;173 Mha pledged (May 2020). Accompanied by Atlas of 2000 Mha 'deforested and degraded' land considered to be suitable for tree planting that, problematically, includes savannahs and other grassy biomes. According to Lewis, Wheeler, et al. (2019), 43% of new forest pledges are commercial plantations. https://www.bonnchallenge.org/
New York Declaration on Forests	Voluntary commitment signed at UN summit in 2014. Governments, businesses, NGOs, communities.	Halve deforestation and restore 150 Mha forests by 2020. Target not met (NYDF Assessment Partners, 2019). https://forestdeclaration.org/
Trillion Trees	BirdLife International, Wildlife Conservation Society and World Wide Fund for Nature	End deforestation/improve forest protection and restore forests. Emphasis on 'right tree, right place'. https://www.trilliontrees.org/
Trillion Tree Campaign	Plant for the Planet (NGO supported by UN)	Plant 1 trillion trees; 13.8 billion planted by May 2020. Campaign initiated by children; builds on earlier UN billion trees target. Donations fund a productive plantation in Mexico, and app gathers details of trees planted elsewhere. Assumes that 1 trillion trees will offset 25–33% of anthropogenic CO_2 emissions released so far. Sweeping statements used such as 'Trees can be planted almost anywhere'. https://www.trilliontreecampaign.org/
Trillion Tree Platform	World Economic Forum	Conserve, restore and grow 1 trillion trees by 2030. Platform to support the Trillion Trees community and the UN Decade on Ecosystem Restoration 2021–2030, led by UNEP and FAO. Website states that tree planting is 'not a silver bullet'. https://www.1t.org/
WeForest	NGO offering carbon offsets to companies	Transform 250 kha of forest landscape by 2021; restore 25 kha of forest with 25 million trees; use FLR best practice across different ecosystems. https://www.weforest.org/
Ecosia	Ecosia internet browser	Plant 1 billion trees; 116 million trees planted by 2020, across 9000 tropical sites. Many projects involve agroforestry, for example, with cocoa or bamboo. Free internet browser that uses the profit from searches to fund tree-planting. https://info.ecosia.org/what
Regional initiatives—related to Bonn Challenge and/or New York Declaration on Forests		
African Forest Landscape Restoration Initiative (AFR100)	$1.4 billion from Germany and the World Bank to African governments.	100 Mha FLR by 2030. According to Bond et al. (2019), much of this will be commercial plantations and much will be on savannah. https://afr100.org/
Initiative 20 × 20	$2.4 billion so far, from impact investors and businesses.	20 Mha of degraded land in Latin America and Caribbean brought into restoration (FLR) by 2020 achieved. Next goal: additional 30 Mha by 2030. Includes timber plantations. https://initiative20x20.org/
ECCA30	European, Caucasian and Central Asian governments and investors	30 Mha FLR in Europe, the Caucasus and Central Asia by 2030. https://infoflr.org/bonn-challenge/regional-initiatives/ecca30
Agadir commitment	Mediterranean governments and investors.	8 Mha FLR by 2030 in Algeria, France, Iran, Israel, Lebanon, Morocco, Portugal, Spain, Tunisia, and Turkey. Supported by CBD Secretariat, FAO, IUCN, WRI, GPFLR, World Bank, Global Mechanism, Union for the Mediterranean, Plan Bleu, EFIMED, MMFN, CTFC. https://www.unccd.int/news-events/agadir-commitment-restore-8-million-hectares-forest-ecosystems
Other regional initiatives		
EU Biodiversity Strategy to 2030	European Union	Plant 3 billion trees by 2030, including in urban and rural areas (European Commission, 2020).
National initiatives		
Grain for Green Program	Chinese Government (1999–2018)	29 Mha of trees planted across China to reduce severe soil erosion and land degradation (Xian et al., 2020).
UK Nature for Climate Fund	£640 M from the UK government.	Plant 30 kha of trees and restore 35 kha of peatland in England by 2025. https://www.gov.uk/government/news/budget-2020-what-you-need-to-know

(Continues)

TABLE 2 (Continued)

Name	Organizers/funders	Targets and methods
Green Legacy Programmes	Ethiopian government	Plant 20 billion seedlings over 4 years. Planted 4 billion seedlings in 2019, including 350 million in one day. The target for 2020 was 5 billion seedlings. Planting in rural and urban areas. https://www.worldagroforestry.org/blog/2020/06/09/ethiopia-grow-5-billion-trees-second-green-legacy-campaign
One Billion Trees Programme	New Zealand Government	Plant 1 billion trees by 2028; 149 million planted so far. https://www.mpi.govt.nz/forestry/funding-tree-planting-research/one-billion-trees-programme/about-the-one-billion-trees-programme/
National Greening Program	Government of the Philippines	Restore 1.5 Mha of degraded forest 2011-2016 – achieved. Now extended to restore the remaining 7.1 Mha of degraded forest land by 2028, with the aim of providing forest products, reducing poverty and enhancing the carbon sink (DENR, n.d.). https://www.denr.gov.ph/index.php/priority-programs/national-greening-program

TABLE 3 Examples of recent corporate funding pledges for nature and climate

Company	Fund (sum)	Pledge details	Reference
Amazon	Right Now Climate Fund ($100 million)	Restore and conserve forests, wetlands and peatlands for carbon storage. The fund forms part of the company's pledge for carbon neutrality by 2040.	Amazon (2020)
	Jeff Bezos Earth Fund ($10 billion)	Fund activists, scientists and NGOs to protect the natural world.	Cohen (2020)
Apple	Carbon Solutions Fund	Restore and protect natural ecosystems through a community-driven approach, including savannahs in Kenya, and 27,000 acres of mangroves in Colombia. This forms part of Apple's pledge for net-zero emissions in its supply chain and product life cycles by 2030; 75% of this will come from emission reductions, the remaining 25% from offsets through NbS funded by the Carbon Solutions Fund.	Apple (2020)
Delta Airlines	Delta Environmental Sustainability Principles ($1 billion for C neutrality; not all specified for NbS)	Investment over 10 years (2020–2030) in carbon removal through forestry, wetland restoration, grassland conservation, marine and soil carbon capture, and other negative emissions technologies. This forms part of Delta's aim to be the first carbon neutral airline.	Delta (2020)
Heathrow airport	Heathrow 2.0 (sum not specified)	UK-based offsetting since 2018, focussing on peatland restoration, to offset emissions from the airport itself. Heathrow also aim to offset emissions from all flights, through the UN's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) which involves emissions trading. They are also working with NGOs, public and private sectors to create a market for ecosystem services from UK ecosystems. Use of nature-based offsets forms part of Heathrow's roadmap for 'carbon neutral growth'.	Heathrow Airport Limited (2018)
Mastercard and Partners	Priceless Planet Coalition (sum not specified)	The coalition (including other partners such as Citibank, Santander UK and HIS Markit) pledged to plant 100 million trees over 5 years (2020–2025), with planting managed by Conservation International and the World Resources Institute.	Mastercard (2020); Seymour (2020)
Microsoft	Biodiversity Initiative (sum not specified)	Protect more land than the company uses by 2025, through land acquisition, national park creation and community or indigenous-led conservation. Microsoft has also committed to planting 250,000 trees in 2020 alone. This is in addition to the Carbon Initiative, which commits the company to being carbon negative by 2030.	Smith (2020)
Salesforce	Founding member of 1t.org	Goal is to support and mobilize the conservation, restoration and growth of 100 million trees by the end of 2030.	Salesforce (2020)
Shell	NbS Programme (£300 M/year 2019–2021)	Investment in NbS such as restoration and protection of forests, grasslands and wetlands, as a form of offsetting for fuel use by customers at about 1400 fuel stations. The investment in NbS will go beyond the initial 3 years, for example, they aim to plant 1 million trees over 5 years in Scotland. This is part of Shell's plan to reach net-zero emissions by 2050: 65% by emission reduction and 35% by offsetting, including the NbS programme (but see Section 6.1).	Shell (2019a, n.d.)
Unilever	Climate and Nature Fund (€1 billion)	Ecosystem restoration, protection and water security projects. This is in addition to committing to deforestation-free supply chains by 2023, and net-zero emissions for all products by 2039.	Unilever (2020)

(EC), with more focus on urban green infrastructure (GI; European Commission, 2015).

Both the IUCN and EC definitions of NbS highlight the multiple benefits that can be derived by working with nature (Table 1). The IUCN frames these in terms of biodiversity and human well-being while the EC emphasizes innovation and economic cost-effectiveness, aiming to 'harness the power and sophistication of nature to turn environmental, social and economic challenges into innovation opportunities', including through biomimicry and urban green infrastructure as well as working with rural ecosystems (European Commission, 2015). The IUCN definition is more widely used and forms the basis of the Global Standard for NbS (see Section 7.2).

NbS has found resonance as an umbrella term that embraces different concepts that involve working with nature for societal benefits, such as the ecosystem approach, ecological restoration, ecological engineering, agroecology, EbA, REDD+, forest and landscape restoration (FLR), ecosystem-based disaster risk reduction (eco-DRR), GI and more recently, natural climate solutions (NCS; Table 1). Some terms are defined based on their intended outcome (e.g. EbA, eco-DRR, NCS) while others are defined by the specific actions involved (e.g. ecological restoration, GI). Accordingly, these terms are not mutually exclusive, and a single NbS may qualify as several of them. For example, the restoration of a mangrove forest may reduce coastal flooding locally and thereby qualify as EbA and eco-DRR; if it also increases carbon storage, it could also be classified as an NCS. Meanwhile, depending on the specific actions involved, such an intervention could also be termed ecological restoration or ecological engineering. A major advantage of applying the NbS concept is that it encourages recognition of a wider range of outcomes of a given intervention than these more specific terms. Referring to a restoration project as NbS rather than NCS or eco-DRR avoids the implication that the sole purpose and outcome of the project is either storing carbon or reducing floods and landslides. By considering the full range of potential outcomes, the NbS concept helps practitioners to design and implement interventions in nature that provide multiple benefits and to manage any trade-offs.

3 | BIODIVERSITY AND PEOPLE AT THE FOUNDATION OF NATURE-BASED SOLUTIONS

Well-designed NbS are place-based partnerships between people and nature. Here we discuss the two key elements that underpin successful, sustainable NbS: biodiversity and people.

3.1 | Biodiversity underpins the benefits delivered by NbS

Biodiversity is the diversity of life from the level of gene to the level of the ecosystem (CBD, 2009). In this paper, we use this term to refer to ecologically appropriate levels of diversity needed to support healthy, well-functioning ecosystems that support local habitats and species, bearing in mind that some ecologically valuable ecosystems naturally host fewer species than others.

There has been some confusion about the relationship between biodiversity and NbS. Some definitions do not explicitly reference biodiversity (e.g. European Commission, 2015), and concerns have been raised that some interventions badged as NbS may ultimately be harmful for biodiversity. Here we argue that because biodiversity is essential to secure the flow of ecosystem services now and into the future (Cardinale et al., 2012; IPBES, 2019; Seddon et al., 2016), NbS must deliver benefits for biodiversity, as well as people. This is in line with the IUCN definition and the Global Standard for NbS (Cohen-Shacham et al., 2019; IUCN, 2020), and it clearly distinguishes NbS from actions that exploit nature but can damage biodiversity, such as certain types of agriculture, BioEnergy Carbon Capture and Storage (BECCS), commercial forestry and recreational activities that harm sensitive habitats or species.

Actions that support biodiversity underpin societal benefits in two ways: they boost the delivery of many ecosystem services in the short term, and they support the health and resilience of ecosystems in the long term, that is, their ability to resist or quickly recover from perturbations. In the short term, more biodiverse ecosystems have greater productivity and, in general, a higher level of ecosystem service provision (Cardinale et al., 2012; Tilman et al., 2012). For example, coral reef fish diversity (which can be enhanced by establishing marine-protected areas) has a strong positive relationship with fish biomass and productivity (Benkwitt et al., 2020) while soil biodiversity (which can be improved using agro-ecological practices) can increase crop yields (Bender & van der Heijden, 2015; Vignola et al., 2015). Cultural ecosystem services are also enhanced: more species-rich green spaces have been shown to support greater personal wellbeing (Aerts et al., 2018), and more visitors are attracted to protected areas with more habitat types and threatened species (Siikamäki et al., 2015) and/or higher bird species richness (Naidoo & Adamowicz, 2005).

Diversity is not always associated with higher delivery of short-term benefits. For example, high-yielding monoculture crops or plantations can produce more food or wood per hectare for a few years compared to a mixed species system (Smith et al., 2017). However, diversity is essential for long-term sustainability, as functional resilience to stressors such as climate change, invasive species and new pathogens is strongly determined by ecosystem connectivity and biodiversity at multiple trophic levels (Oliver et al., 2015). Connectivity of similar ecosystems across landscapes enables recovery of disturbed habitats by facilitating dispersal from surrounding intact areas. Connectivity also allows allow species to track their preferred ecological niches across the landscape in response to changing environmental conditions (Biggs et al., 2012). Meanwhile, the diversity of species, ecological traits and genes contained within communities of plants, animals, fungi and bacteria buffers ecosystems against perturbation via 'insurance effects', that is, spatial and temporal complementarity in ecological functions, as well as by functional redundancy among multiple taxa (Alvarez et al., 2019;

Biggs et al., 2020; Cardinale et al., 2012; Tuck et al., 2016; Yachi & Loreau, 1999). For example, natural forests and mixed species forest plantations have more stable carbon stores during climate extremes compared to species-poor plantations (Hutchison et al., 2018; Osuri et al., 2020), as do high diversity grassland plots compared to low diversity plots (Isbell et al., 2017). Compared to low diversity plantations, biodiverse natural forests and areas allowed to regenerate naturally also have higher resilience to fires, pests and diseases (Barlow et al., 2007; Jactel et al., 2017). In marine ecosystems, greater species turnover among reefs (β-diversity) increases community stability (Mellin et al., 2014) and possibly also resistance to disturbance (Mellin et al., 2016). Therefore in order to maintain healthy, resilient ecosystems that can continue to deliver benefits to people over the long term, NbS must be explicitly designed to protect or enhance biodiversity (Figure 1).

3.2 | NbS with and for people

To deliver effective, resilient, legitimate and equitable outcomes, all relevant stakeholders (especially Indigenous Peoples and local communities, IPLCs) should be engaged in the design, implementation, management, monitoring and evaluation of NbS, and interventions should foster ownership, empowerment, and wellbeing of the local stewards shaping the landscapes in which they take place (Mercer et al., 2012). Such engagement is not only a moral and ethical imperative and can prevent perverse intervention outcomes on IPLCs (Section 6.3), but it also underpins the success of NbS for several reasons. First, as the stewards of their lands and natural resources, IPLCs often have rich knowledge of local ecosystems and their management, based on adaptive learning and lessons from past mistakes, with insight into what works in their specific environmental, socio-economic and political context (Appadurai, 2018; Chaterjee, 2020). If external 'experts' undermine or ignore local knowledge, this could result in poor and ineffective land management decisions (Leach & Mearns, 1996). Second, co-creating NbS with IPLCs and tailoring them to the local context can facilitate adaptive management wherein interventions are modified to keep pace with environmental and socio-economic changes (Sterling et al., 2017). Third, local information about the diverse values of nature and how these differ across different sectors of society is crucial to the equitable distribution of benefits (Zafra-Calvo et al., 2020). Fourth, NbS involving a more equitable distribution of power between local communities and government, such as community managed forests, are more likely to have positive outcomes for both people and the ecosystems on which they depend (Hajjar et al., 2020). In part, this is because such interventions empower and motivate marginalized groups (such as women or Indigenous Peoples) who have access to, and control over, key resources. Finally, NbS that take account of diverse local norms, values, beliefs, and build social capital are more likely to be adopted by IPLCs and supported longterm. Importantly, such NbS tap into relational and moral values, including intangible connections to nature, which also encourages stewardship and care (Chan et al., 2016; Fischer et al., 2020). This can strengthen core motivations to implement NbS, promoting their scaling-up across landscapes (Fedele et al., 2018). In contrast, a lack of alignment with local perspectives can deter active participation and disempower local communities, which, in turn, can compromise local support for NbS, jeopardizing their success (Woroniecki et al., 2020; see Section 6.3), while also constraining local adaptive capacity (Woroniecki, 2019).

4 | MAINSTREAMING OF NATURE-BASED SOLUTIONS

4.1 | Growth of research on NbS and recent global syntheses

Research into NbS has grown very rapidly in recent years (Hanson et al., 2020; Keesstra et al., 2018; Raymond et al., 2017; Seddon, Chausson, et al., 2020). A review by Hanson et al. (2020) found the term 'nature-based solution(s)' in 112 retrievable peer-reviewed articles or reviews in Web of Science and Scopus up to May 2018, but using the same search methodology in August 2020 we found a total of 648 papers. Over half of the articles up until May 2018 addressed the role of NbS for adaptation to climate impacts in urban environments, with a focus on flood mitigation (Hanson et al., 2020), largely reflecting funding from the EC as part of its 'Horizon 2020' programme launched in 2015 (European Commission, 2015; Faivre et al., 2017; Maes & Jacobs, 2017). However, relevant research that does not use the specific term 'NbS' has a much longer history, with published articles going back to at least 1988. These interventions are labelled using older green concept names (Table 1) or are simply described as protection, restoration or management of ecosystems, nature or biodiversity (Chausson et al., 2020).

NbS were highlighted in all the recent global assessment reports synthesizing evidence from science and practice on the state of the biosphere and climate. The Global Commission on Adaptation Report described the value of nature in reducing vulnerability across multiple sectors, and estimated that the benefits of mangrove protection and restoration (for fisheries, forestry, recreation and disaster risk reduction) are up to 10 times greater than their costs (GCA, 2019). The IPBES Global Assessment also highlighted the fundamental role of natural ecosystems in 'reducing vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters' (IPBES, 2019). IPBES described NbS and 'nature-friendly' solutions as cost-effective ways of meeting the Sustainable Development Goals. At the same time, it urged caution around large-scale bioenergy plantations with carbon capture and storage (BECCS) and widespread afforestation of non-forest ecosystems as these would have negative impacts on biodiversity, food and water security and local livelihoods, including by intensifying social conflict.

A similar mix of endorsement and caution around NbS can be found in the three Special Reports produced by the IPCC since 2018. The Special Report on global warming of 1.5°C above pre-industrial levels (IPCC, 2018) concluded that 1.5°C warming will be surpassed within a few years unless transformational change reduces emissions at an unprecedented rate. The four IPCC pathways that stay within 1.5°C of warming all assume some deployment of 'carbon dioxide removal' options, including BECCS, afforestation (planting on naturally open landscapes), reforestation (planting on previously forested landscapes), land restoration and soil carbon sequestration, with the adverse impacts of BECCS and afforestation acknowledged. A range of NbS were also mentioned as potential adaptation options, including EbA, ecosystem restoration, avoided deforestation and GI.

The Special Report on the Oceans and Cryosphere in a Changing Climate (IPCC, 2019a) recognized NbS, in the form of community-supported terrestrial and marine habitat restoration, as a key approach to reducing climate risk and enhancing adaptation along coasts. However, it emphasized that such benefits might not be deliverable above 1.5°C warming as the multiple adverse impacts on marine and coastal biodiversity, including a loss of resilience through extinctions or redistribution of species, will erode the capacity of habitats to protect communities and infrastructure.

Finally, the Special Report on Climate Change and Land examined the effects of climate change and land use and management on land degradation, desertification, the ability to adapt to and mitigate climate change, and food security (IPCC, 2019b). It found that climate change is exacerbating existing pressures on terrestrial ecosystems, but found that a number of interventions, including various forms of sustainable land management, could address these challenges. Many of these interventions could be considered NbS, or a mix of NbS and other approaches. However, it was noted that although such interventions could deliver multiple benefits, land-based mitigation is only effective if immediate and aggressive greenhouse gas emission reduction is introduced in all sectors of the economy (Anderson et al., 2019; Smith et al., 2019).

In summary, the concept of NbS has expanded from an initial focus on ecosystem-based adaptation to encompass urban green infrastructure, climate change mitigation, sustainable agriculture and many other concepts (Table 1). The potential of NbS is now recognized by all the major international scientific bodies working on climate change and biodiversity, and there is a growing consensus around key caveats concerning the limits of NbS for climate mitigation, the potential adverse impacts of some actions on biodiversity and food security, and the need to accompany NbS with deep cuts to fossil fuel emissions.

4.2 | Governmental and non-governmental interest in nature-based solutions

Over the last few years, numerous national, intergovernmental and government-NGO commitments involving NbS have been made. The majority (66%) of the world's nations have committed to implementing NbS in some form to address the causes and consequences of climate change in their Nationally Determined Contributions (NDCs), the climate pledges produced by signatories of the Paris Agreement (Seddon, Daniels, et al., 2020; Seddon, Sengupta, et al., 2019). Most of the high-level government targets for NbS focus on forests. For example, nearly half of the 64 adaptation targets included in 30 NDCs involve the protection and/or restoration of forest, and afforestation accounts for 22% of nature-based adaptation targets (Seddon, Daniels, et al., 2020). Similarly, 42 nations have committed to collectively bringing 350 million hectares of deforested and degraded land into restoration by 2030 as signatories of the Bonn Challenge; and 41 national and 21 subnational governments (together with 61 companies, 22 Indigenous groups and 66 non-governmental organizations) have pledged to halt deforestation by 2030 as signatories of the New York Declaration on Forests. Meanwhile, 32 countries plus the EU Commission have joined an 'NbS coalition' with eight private sector groups and coalitions and 21 civil society organizations, and have signed the Nature-based Solutions for Climate Manifesto to 'acknowledge the important role of nature in climate action and commit to unlocking its full potential through a range of actions' (UNEP, 2019). As part of, or in addition to, these commitments, several national governments as well as the European Union have pledged to plant billions of trees and several major NGO initiatives on NbS have been established (Table 2). NbS are also one of five major action tracks at the upcoming UK-hosted CoP26 (Defra, 2020). Most recently, the Leaders Pledge for Nature (http://www.leaderspledgefornature.org/), spearheaded by the UK government, commits signatories (83 nations so far) to cooperating and holding one another to account in their joint mission to reverse biodiversity loss by 2030.

4.3 | Private sector interest in nature-based solutions

Appreciation of the critical importance of healthy, functioning ecosystems to human wellbeing and economic activity has also grown in the private sector in recent years (Dasgupta, 2020; IPBES, 2019; WEF, 2020b), where it is increasingly acknowledged that the loss and degradation of natural ecosystems brings 'operational risks; supply chain continuity, predictability and resilience risks; liability risks; and regulatory, reputational, market and financial risks' (WEF, 2020b). For the past 6 years, the World Economic Forum (WEF) has listed failure to mitigate and adapt to climate change, extreme weather or natural disasters, and biodiversity loss/environmental damage as the top three risks most likely to damage the global economy in terms of severity of impact and/or likelihood of occurrence (WEF Global Risks Reports 2015–2021). On the basis of an analysis across 163 economic sectors, the WEF also estimated that all businesses depend on nature either directly or through their supply chains, and that at least $44 trillion of economic value generation (over half of global GDP) is dependent on nature and its services to people (WEF, 2020a).

In recognition of this, a coalition of over 50 organizations called 'Business for Nature' (https://www.businessfornature.org/) has formed with members including the World Economic Forum, World Business Council for Sustainable Development, the We Mean Business Coalition, the International Chamber of Commerce and groups representing companies on nearly every continent. Business for Nature lays out the rationale for companies to support NbS and has encouraged, as of January 2021, 530 companies to commit to reversing nature loss and restoring vital natural systems on which economic activity depends, mainly through business partnerships. An example is the AgWater Challenge which develops time-bound and measurable commitments to reduce the impact of agricultural commodities on water resources. The Capitals Coalition is another prominent business-oriented group that provides practical tools to help companies assess their dependence on and impacts on nature via the Natural Capital Protocol (NCC, n.d.). Meanwhile, the 1t.org (of the World Economic Forum) has a cross-industry corporate alliance and intends to be the 'pinnacle for corporate leadership in this space'.

As well as these pro-nature commitments, there has been a sharp rise in major funding pledges for NbS from the private sector (Table 3). While many of these pledges refer to a wider range of NbS options than just tree planting, there is very little publicly available information to determine the extent to which these pledges have been implemented, nor on key details such as the type of NbS, species selected (i.e. native or non-native) and the previous use of the land.

5 | THE PROMISE OF NATURE-BASED SOLUTIONS

NbS offer multiple benefits for people and nature (Figure 1). However, much recent attention has focused on their potential for addressing climate change in particular. Here we provide an overview of the strength of the evidence supporting a role for NbS in both climate change adaptation and mitigation.

5.1 | Adaptation benefits of nature-based solutions

NbS can reduce the vulnerability of the social-ecological system (i.e. the interconnected ecological and socio-economic systems) to environmental shocks and changes in three ways: by reducing exposure to climate hazards; reducing sensitivity to adverse impacts; and building adaptive capacity (Seddon, Chausson, et al., 2020).

There is now a substantive evidence base demonstrating that NbS can reduce exposure to climate impacts such as flooding, erosion, water scarcity and reduced agricultural productivity (Chausson et al., 2020). For example, restoring and protecting coastal ecosystems can defend against flooding and storm surges while restoration and protection of forests and wetlands can improve water security, and reduce risk of floods, soil erosion and landslides (see examples in Seddon, Chausson, et al., 2020); nature-based agriculture (e.g. agroforestry) can increase resilience of food supplies to pests, diseases and climatic extremes (Altieri et al., 2015; Tamburini et al., 2020; Vignola et al., 2015); and urban NbS can make a key contribution to flood mitigation (Stefanakis, 2019) and cooling cities (Kabisch et al., 2016; Marando et al., 2019).

NbS can also reduce the degree to which individuals, communities and societies are actually affected by the climate impacts they experience, that is, their social sensitivity (e.g. Valenzuela et al., 2020). In particular, NbS secure the delivery of a wide range of benefits that sustain diverse sources of food and income, which can provide nutritional and financial security when crops or usual sources of income fail in the face of climate extremes (Ahammad et al., 2013; Seddon, Chausson, et al., 2020; Waldron et al., 2017). This is particularly important in the Global South where dependency on local natural resources for food and income is high (Uy et al., 2012). For example, in Vanuatu, marine protected areas act as a reservoir of resources that can be temporarily opened to fishing as a source of food and income for the local communities, when terrestrial-based livelihoods are reduced due to drought from El Niño (Eriksson et al., 2017).

NbS can also build the adaptive capacity of local communities to future stressors through participatory design, implementation and management of NbS. Giving local people leadership roles and supporting them to govern their own resources can strengthen their ability to address future climate hazards. For example, community-based forest management can build social cohesion and empowers women by providing them with natural resource management training, thus increasing participation in creating adaptation strategies (Lin et al., 2019). These benefits to social capital can feed back into improved and sustained stewardship of the ecosystem to ensure the continued supply of nature's benefits (Valenzuela et al., 2020). For additional examples of how NbS can reduce vulnerability to climate change, see Seddon, Chausson, et al. (2020).

Adaptation outcomes of investments in nature depend on many locally specific biophysical, ecological and socioeconomic factors, including stakeholder perspectives (Arkema et al., 2017; Bouma et al., 2014; Gómez Martín et al., 2020; Woroniecki, 2019). Indeed, no single metric can capture the aggregate effect of any system or intervention, nature-based or otherwise, on the complex, multidimensional process of climate change adaptation. In other words, there is no adaptation equivalent for the simple metric of Gt CO_2e used to measure GHG reduction (Owen, 2020). Nevertheless, there have been attempts to quantify the effects of NbS for adaptation at regional or global scales, using a range of metrics such as number of people affected, the monetary value of avoided damage to infrastructure/property (from floods, fires, landslides, etc.), or the market value of provisioning services such as timber or fish. Several such studies come from coastal ecosystems (e.g. Smith et al. (2020) on wetlands, Beck et al. (2018) on coral reefs, Menéndez et al. (2020) on mangroves, and Van Coppenolle and Temmerman (2020) on salt marshes). Taken together, these studies indicate that the protection of coastal ecosystems could benefit upwards of 500 million people globally, bringing benefits of over $100 billion per annum. Increasing the extent of these coastal ecosystems through restoration would amplify these effects. For inland ecosystems, afforestation/reforestation and improved and sustainable forest management are both estimated to provide climate adaptation benefits for >25 million people, and reduced deforestation is estimated to benefit 1–25 million people (Smith et al., 2019).

5.2 | Mitigation benefits of nature-based solutions

Intact ecosystems act as carbon sinks, but agriculture, forestry and other land-use activities (AFOLU) emit CO_2, methane and nitrous oxide, accounting for around 23% of total net anthropogenic emissions of GHGs (12.0 ± 3.0 Gt CO_2e year^{-1}) (IPCC, 2019b). Terrestrial ecosystems currently sequester c. 29% of annual anthropogenic CO_2 emissions (11.2 ± 2.6 Gt CO_2 year^{-1}; IPCC, 2019b), and oceans remove c. 24%, although their carbon cycle is less well understood (Friedlingstein, Jones, et al., 2019; Howard et al., 2017; Siikamäki et al., 2013).

NbS can increase the size of the land and ocean carbon sinks, and reduce the release of GHGs driven by human activities in the AFOLU sector, making a critical contribution to climate change mitigation this century. Protecting intact ecosystems such as forests, wetlands, kelp forests and seagrass meadows limits CO_2 emissions; restoring native vegetation cover enhances CO_2 removal from the atmosphere; and improving the management of working lands (e.g. plantations, cropland, pastures) can significantly reduce CO_2, methane, and nitrous oxide emissions, and sequester carbon (Busch et al., 2019; Friedlingstein, Allen, et al., 2019; Girardin et al., in press; Griscom et al., 2017; Lewis, Mitchard, et al., 2019; Roe et al., 2019). Urban green infrastructure is often overlooked, but there is a growing evidence that urban trees can also make a significant contribution to mitigating GHG emissions (Davies et al., 2011; De la Sota et al., 2019; Nowak et al., 2013).

A number of recent studies have attempted to estimate the contribution that NbS could make to climate change mitigation this century, if scaled up globally. Estimates vary as they depend on assumptions about a wide range of factors such as future trends in land sector demand (e.g. meat consumption) and supply (e.g. agricultural productivity); the price of carbon, which increases with climate change mitigation ambition; and the carbon saturation point of mature ecosystems (e.g. in forests, this ranges from 50 to 100 years (Griscom et al., 2017, 2020) up to several centuries (Kohl et al., 2017; Luyssaert et al., 2008)). Estimates also vary because they differ in the extent to which they consider constraints on deployment of NbS related to economic and political feasibility, land rights and local needs, and safeguards for food security and biodiversity (Zeng et al., 2020). The models developed by Griscom et al. (2017), for example, only include reforestation in areas ecologically appropriate for forests; this excludes boreal systems, where the albedo effect may lead to net warming (Betts & Ball, 1997) and afforestation of native non-forest habitats such as savannahs (Bond et al., 2019).

The total mitigation potential of improvements in the land-use sector, including coastal ecosystems, estimated by Roe et al. (2019) is 10–15 Gt CO_2e year^{-1}. However, this includes BioEnergy Carbon Capture and Storage (BECCS), which is not an NbS under the IUCN and EC definitions. When we exclude BECCS, the total global mitigation potential comes to around 11 Gt CO_2e year^{-1}, an estimate that closely aligns with that of Griscom et al. (2017). Given the wide range of assumptions involved in running these models, these estimates should be regarded as rough approximations at best. Moreover, while the models include coastal ecosystems (mangroves, saltmarshes and seagrass) they exclude marine systems such as coral reefs, phytoplankton, kelp forests and marine fauna, that is, calcifiers (shellfish, zooplankton), krill and teleost fish, for which data remain sparse and estimates highly uncertain (Howard et al., 2017; Siikamäki et al., 2013).

Despite these sources of uncertainty, an influential oft-cited statement regarding NbS has been circulating in business and policy discourse: decreasing sources and increasing sinks of GHGs through NbS have the potential to provide around 30% of the cost-effective climate mitigation needed through to 2030 to achieve the targets of the Paris Agreement (CBD, 2020). However, this statement is not always accompanied by the essential caveat that this potential can only be achieved in tandem with the decarbonization of the global economy at unprecedented rates. If global mean annual temperature increases beyond 1.5°C, the carbon balance of many ecosystems will be adversely affected and they will turn from net sinks to net sources of GHGs (Frank et al., 2015; Hubau et al., 2020; IPCC, 2018; Turetsky et al., 2019; Turner et al., 2020).

Acknowledging the problems associated with a carbon emissions-centred framing for estimating the potential of NbS to mitigate climate change, Girardin et al. (in press) provide a new approach by modelling the extent to which NbS could limit peak warming observed this century. Based on the model presented in Griscom et al. (2017, 2020), they estimate that the most significant contributions for cost-effective (less than US$100 per $MgCO_2e$) avoided emissions of CO_2 come from protecting intact forests, wetlands and grasslands (4 Gt CO_2 year^{-1}) while the greatest potential contribution to the global carbon sink comes from managing timberlands, croplands and grazing lands (4 Gt CO_2 year^{-1}) and by restoring native forests and wetlands (2 Gt CO_2 year^{-1}; Girardin et al., in press). Therefore the total mitigation potential of land-based NbS is around 10 Gt CO_2 year^{-1}. According to Girardin et al. (in press), this translates into reducing global warming by 0.1°C if warming peaks mid-century at 1.5°C. However, if warming peaks later in the century at 2°C, there would be more time for the benefits of NbS to accrue and they would reduce peak warming by 0.3°C. In other words, if scaled up to the maximum extent possible, NbS would make an important contribution to limiting climate change, especially later this century. However, their potential is relatively small compared to what can be achieved by the rapid phase out of fossil fuel use.

It is important to note that many NbS for climate change mitigation also hold potential for climate change adaptation, and vice versa, although few studies report on both outcomes. In the systematic map by Chausson et al. (2020), only 13% of studies investigating adaptation outcomes of NbS reported effects on GHG mitigation outcomes, but most of these (76%) were positive and none reported exclusively negative effects, while 22% reported mixed or unclear effects. For example, protection or restoration of mangroves or woodlands can enhance carbon sequestration as well as providing flood and erosion protection; while adding organic matter to soil will enhance soil carbon as well as conserving moisture during droughts. However, more research is needed to clarify the types of interventions that can effectively and sustainably deliver positive adaption and mitigation outcomes, and the spatial and temporal scales over which those benefits materialize, and for whom.

6 | POTENTIAL PITFALLS OF NATURE-BASED SOLUTIONS

The endorsement of NbS by governments, NGOs and businesses across the world is to be welcomed. However, a number of challenges are emerging. NbS can distract from the need for systemic change, including rapid phase out of fossil fuel use, and there is an over-emphasis on planting trees rather than investing in a wide range of ecosystems. In this section, we consider how poorly designed NbS can cause adverse impacts for climate mitigation, local communities, biodiversity and ecosystem services.

6.1 | NbS can distract from the need to decarbonize energy systems

NbS are increasingly being promoted as a climate change mitigation solution. Voluntary carbon markets are growing rapidly, with carbon offsets doubling from 2017 to 2020, and the new Taskforce on Scaling Voluntary Carbon Markets aims to accelerate this (TSVCM, 2020). This has been fuelled by influential estimates of the potential for 'Natural Climate Solutions' that are optimistic upper limits (Griscom et al., 2017, 2020, Section 5.2), or simply incorrect (Bastin et al., 2019, see critiques: Friedlingstein, Allen, et al., 2019; Lewis, Mitchard, et al., 2019; Veldman et al., 2019; and the correction: Science, 2020). While protection of the carbon stored in intact terrestrial, coastal and marine ecosystems is critical (Solan et al., 2020; Watson et al., 2018), over-reliance on NbS as a cheap offsetting option in corporate mitigation policies or as a political fig-leaf risks distracting from the urgent need for aggressive and rapid greenhouse gas emission reduction in all sectors of the economy (Anderson et al., 2019; Friedman, 2020; Griscom et al., 2019).

A number of high emitting industries are now proposing to use NbS to offset their greenhouse gas emissions, including airports (Heathrow Airport Limited, 2018), airlines (Delta, 2020) and oil and gas companies (Shell, 2019b). Use and marketing of NbS (and other carbon dioxide removal options) creates a 'moral hazard' because it enables companies to claim carbon neutrality without cutting emission production, thus slowing global progress towards net-zero while encouraging customers to drive or fly more, or to view mitigation policies generally as being less necessary (Anderson & Peters, 2016; Campbell-Arvai et al., 2017; Daggash & Mac Dowell, 2019). For example, customers purchasing Shell Go+petrol (gasoline) have been told that they can 'drive carbon neutral' through the use of nature-based carbon offsets (Shell, 2019c).

This is also problematic because there are limits on the extent to which NbS can contribute to offsetting continued fossil fuel emissions. Constraints on land area and tree growth dynamics limit the amount of carbon that can ultimately be removed by tree planting or forest regrowth (Pugh et al., 2019). Using NbS as offsets is also risky, because of the chance of stored carbon being released at a later date. Without rapid phase out of fossil fuel use, climate change threatens to turn emission sinks into sources, as vegetation becomes stressed, wildfires become more frequent, and soils and oceans warm (IPCC, 2019b).

This creates a dilemma: high-emitting industries can provide substantial funding for ecosystem restoration ($300 M in the case of Shell Go+), but this promotes continued fossil fuel use which is incompatible with long-term climate targets. The concept of NbS has, in some cases, been co-opted for corporate greenwashing. The challenge is how to direct funding towards well-planned NbS projects that do not delay decarbonization. Part of the solution may be to allow companies to claim NbS offsets only if they meet stringent criteria for reducing emissions throughout their operations and supply chains (e.g. Oxford Principles for Net Zero Aligned Carbon Offsetting; Allen et al., 2020), as well as adhering to the IUCN Global Standard for NbS to ensure the quality of offset projects (IUCN, 2020).

6.2 | Over-emphasis on tree planting rather than a wide range of NbS

Although NbS span a wide range of actions, from protection and restoration of terrestrial and marine ecosystems to sustainable agriculture and urban green infrastructure (see Table 1), funds are currently being channelled mainly towards tree planting (Table 2). The simple and powerful narrative of 'plant a tree to save the planet' is universally appealing, but over-reliance on tree planting as a climate solution raises a number of concerns (Chazdon, 2020; Holl & Brancalion, 2020). First, planting trees does not equate to establishing a healthy forest with a complex functional web of interactions among multiple species, which often necessitates careful stewardship over many years if not decades. Second, inappropriate tree planting can do more harm than good, especially afforestation of naturally open habitats, or planting on high carbon soils. For example, although afforestation increases topsoil carbon in carbon-poor soils, the associated soil disturbance causes significant losses in carbon-rich soils, especially of the more resilient deep soil carbon which takes many decades to accumulate (Hong et al., 2020). This suggests that the widely used method of estimating soil carbon from a fixed ratio with vegetation biomass overestimates carbon sequestration from afforestation (Hong et al., 2020). Afforestation on peaty soils can lead to losses of soil carbon that outweigh that sequestered as the trees grow (Brown, 2020; Brown et al., 2014; Friggens et al., 2020; Sloan et al., 2018).

Third, afforestation can also reduce ecosystem resilience and thus long-term carbon storage and sequestration. For example, fire-adapted savannah and dryland grassland ecosystems hold large carbon stores below ground. They readily recover from the relatively cool and frequent grassland fires, which do not destroy soil carbon, but afforestation risks much greater carbon losses during intensely hot plantation fires (Bennett & Kruger, 2015), and can also increase the risk of fires on peatland in temperate regions (Davies et al., 2013; Wilkinson et al., 2018).

Fourth, tree-planting schemes must be carefully designed if they are to deliver the intended benefits. For example, mangroves can only thrive in particular conditions of soil, climate, tidal fluctuations and wind velocity (Singh, 2006; Thivakaran et al., 2016). Compensatory offsets and afforestation schemes that ignore these factors have often resulted in slow and stunted growth (Srivastava & Mehta, 2017). Many investments badged as NbS are for commercial plantations, which do not provide permanent carbon stores (Lewis, Wheeler, et al., 2019). Although harvested timber can lock up carbon in long-lived products such as timber-framed buildings or furniture, the carbon stored in these products has been over-estimated (Harmon, 2019). A high proportion of harvested wood is used for paper, card and short-lived products such as MDF furniture, which soon end up in landfill or incineration, releasing carbon back to the atmosphere so that the net result could even be a carbon loss (Hudiburg et al., 2019; Lewis, Wheeler, et al., 2019).

Fifth, trees in the wrong place can also cause trade-offs between ecosystem services. More research is needed into the dynamics of these trade-offs, but current evidence shows that, for example, single-aged, low diversity, intensively managed plantations deliver wood products but may cause water pollution from soil disturbance and agrochemical use (Drinan et al., 2013) and reduce water availability in arid regions (Smith et al., 2017). The Grain-for-Green program in China succeeded in rapidly increasing tree cover to restore degraded agricultural soils, but used mainly fast-growing non-native species that have reduced water supply, and also resulted in a decrease of 6% in native forest cover as farming was displaced to new areas (Chausson et al., 2020; Hua et al., 2018; Xian et al., 2020).

Finally, and critically, the current focus on planting trees is distracting from the urgent need to effectively protect remaining intact ecosystems. Indeed, in the United States, the Trump administration signed up to the World Economic Forum's Trillion Trees initiative while also opening up previously protected forests for logging (Frazin, 2020). Less than 1% of tropical, temperate and montane grasslands, tropical coniferous forests, tropical dry forests and mangroves are classed as intact, that is, having very low human influence (Riggio et al., 2020). Not only are these intact ecosystems hotspots for biodiversity, but intact old-growth forests are particularly important for carbon storage and sequestration (Watson et al., 2018) while also protecting people from climate change impacts (Martin & Watson, 2016). Yet, many of the world's remaining intact ecosystems lack effective protection or are poorly managed (Soto-Navarro et al., 2020; Tan et al., 2020); including marine-protected areas where dredging takes place (McVeigh, 2020). Degradation of terrestrial habitats (e.g. through logging, drainage, infrastructure development) significantly reduces carbon storage (Maxwell et al., 2019; Tan et al., 2020) and increases vulnerability to climate-related hazards such as fire (Barlow et al., 2007). Freshwater, coastal and marine habitats face similar issues due to water pollution, temperature increases, sea-level rise, over-fishing, the spread of invasive species and, in some cases, inappropriate management (Elliott & Lawrence, 1998). A balanced NbS approach would give greater priority to protecting these remaining intact ecosystems, as well as restoring partially degraded forests (Philipson et al., 2020), and other approaches such as 'proforestation'—leaving forests to grow to their full potential, with minimal intervention (Moomaw et al., 2019), and natural regeneration of native ecosystems, where appropriate (Cook-Patton et al., 2020; Guariguata et al., 2019; Holl, 2017; Holl & Aide, 2011; Meli et al., 2017; Molin et al., 2018).

In summary, a more holistic approach is needed which protects, restores and connects a wide range of ecosystems across landscapes and seascapes, including native woodlands, shrublands, savannas, wetlands, grasslands, reefs and seagrass, as well as sustainable agriculture and urban green infrastructure. This will identify which ecosystems are appropriate to suit the local ecological and climate context, and will balance local needs for food and materials with the need to support biodiversity, climate change adaptation and other sustainable development goals. To support investment in a diverse range of habitats, we also need to extend current metrics and standards beyond those used for forest carbon to include other carbon-rich habitats such as wetlands and grasslands.

6.3 | Potential adverse impacts on local communities

Despite the fact that Indigenous Peoples and local communities (IPLCs) can play a key role in tackling the biodiversity and climate crises (Section 3.2), they are often excluded from land-use decisions involving ecosystem protection and management, their rights disrespected (Bayrak & Marafa, 2016).

Where regulatory frameworks are weak, this can facilitate 'green grabbing', that is, appropriation of land and resources for environmental ends (Vidal, 2008), displacing and marginalizing poor and vulnerable communities through securitization of resources (Scheidel & Work, 2018; Veldman et al., 2019).

Failure to involve IPLCs can ignore cultural links that communities have with local ecosystems, as a source of livelihoods and identity (Srivastava & Mehta, 2017; Sullivan, 2009). Some conservation or planting programmes have alienated local communities by using them simply for labour, while restricting their access to what were previously common-pool ecosystem resources (Fairhead et al., 2012; Srivastava & Mehta, 2017). This forces communities to find alternative fishing or hunting areas and can lead to negative impacts on stocks and biodiversity (Mora & Sale, 2011).

As is the case with most development initiatives, NbS programmes evolve in locally specific ways contingent on social, economic and political forces as well as the relative power of various stakeholders (Woroniecki, 2019). Procedural aspects involving local people in decision-making can sometimes be reduced to programmatic formalities and box-ticking exercises (Newell et al., 2020), rather than providing space at the negotiation table to influence the decision-making process. Local communities are often labelled as ignorant and in need of training or capacity building (Li, 2007) rather than being recognized as agents with extensive local knowledge that are capable of exercising choice and making decisions.

Experiences with such poorly implemented 'offset' projects labelled as NbS and their detrimental ecological and social side effects can lead to push-back against NbS from local communities and conservation practitioners. They are also wary of trade-offs that may be generated by NbS where some people benefit at the expense of others. This may arise in situations where there are benefits to project participants but costs to non-participants or where a project benefits all members of a community locally but imposes costs to communities elsewhere (Chausson et al., 2020). For example, an urban shelterbelt in China protects city-dwellers from dust storms, but Uighur communities downstream suffer because the heavy irrigation demand of the shelterbelt is drying out the native riparian forests on which they depend (Missall et al., 2018).

This problem is exacerbated by the misuse of the concept of NbS as a quick 'ecological fix' for the crisis generated by unsustainable patterns of production and consumption (Castree, 2008; Dempsey & Suarez, 2016). For example, using biochar (charcoal) to lock carbon into the soil can be seen as implying that unsustainable practices in one place (fossil fuel emissions) can be repaired by sustainable practices in other places (Fairhead et al., 2012; Leach et al., 2012). Such activities, if not accompanied by larger structural changes in production and consumption including reduced fossil fuel use, may lead to unsustainable outcomes and can marginalize the poor who become committed and reliant on these NbS practices but who have little to no voice in deciding and shaping these systems.

Transitions and finance mechanisms underlying NbS programmes need to be 'just', putting the needs and livelihoods of the most vulnerable at the centre of policy and implementation. For example, communities may need financial support during any lag time taken for NbS to start delivering benefits. Affected communities must be fully included in the decision-making processes, not merely used for labour (Fairhead et al., 2012), and social differentiation (ethnicity, caste, class, gender, ableism) needs to be factored in to ensure that all voices count in the decision-making process. Distributive (who gains and who loses), procedural (who decides for whom) and recognition justice (understanding plural notions of value) need to be incorporated into accountability and regulatory frameworks with compliance being monitored through regular social audits (involving local communities) and third-party actors (including the judiciary). In this way, NbS pathways can disrupt unequal systems of power and enable fair futures for the marginalized and vulnerable groups who are at the frontline of climate change and its impacts.

6.4 | Failure to ensure benefits for biodiversity

Protecting intact terrestrial, freshwater, coastal and marine ecosystems, restoring degraded habitats to their natural state and managing working lands more sustainably can deliver significant biodiversity benefits (Bustamante et al., 2019; Coetzee et al., 2014; IPBES, 2019; Solan et al., 2020). However, as discussed in Section 6.2, investments and policy support are currently being directed largely towards created ecosystems, especially tree plantations. The outcome of these initiatives for biodiversity will depend on many factors, including the species used, the state of the landscape prior to the intervention, the management regime and the scale at which outcomes are measured. For example, agroforestry is likely to have biodiversity benefits compared to conventional arable, pasture or forestry, but this depends on the variety, abundance and ecological suitability of the tree species used (Torralba et al., 2016). Establishing plantations of non-native trees in a highly degraded landscape might benefit biodiversity locally if the trees enable native vegetation to regenerate (Brancalion et al., 2020) or regionally if plantations take pressure off native biodiverse forest (Ghazoul et al., 2019). Conversely, if non-native tree plantations replace intact native ecosystems such as ancient grasslands, peatlands or woodlands, the outcomes for biodiversity will be poor (Balthazar et al., 2015; Barlow et al., 2007; Bond, 2016; Bremer & Farley, 2010; Stephens & Wagner, 2007). Native biodiversity can also suffer if exotic species used in plantations become invasive (García-Palacios et al., 2010), over-dominant (Yu et al., 2012) or reduce water supplies (Missall et al., 2018).

Complex trade-offs can arise, however, which require more research. For example, a modelling study by Ohashi et al. (2019) concluded that although afforestation and BECCS can cause local biodiversity loss in certain regions (Europe and Oceania), it can achieve net biodiversity benefits at the global level through its contribution to mitigating climate change, which is a major driver of biodiversity loss. Yet, if biomass production for BECCs mainly takes place in developing tropical countries where productivity is highest and costs are low, this could exacerbate global biodiversity loss.

Several studies have investigated whether NbS can provide a win–win for biodiversity and climate change mitigation. There can be biodiversity benefits from REDD+ and PES schemes that protect forests for carbon storage, as high-carbon ecosystems often overlap with biodiversity hotspots (Larjavaara et al., 2019). Although conservation priorities sometimes lie in lower carbon ecosystems (Budiharta et al., 2014), research increasingly shows how NbS can effectively support both mitigation and biodiversity goals (Brancalion et al., 2019). For example, conservation actions in areas rich in both carbon and biodiversity were recently estimated to secure nearly 80% of the potential carbon stocks and 95% of the potential biodiversity benefits that would be achievable if either carbon or biodiversity were prioritized alone (de Lamo et al., 2020). Meanwhile, restoring 15% of agricultural and pastoral lands in areas across several biomes that are high priority for both biodiversity and climate mitigation could result in 60% fewer expected species extinctions and sequester nearly 300 Gt of CO_2 (Strassburg et al., 2020). NbS that involve sustainable management of natural or modified ecosystems, such as adding organic matter to soils to improve carbon storage and water retention, would also be expected to have benefits for biodiversity (in this case soil biota).

NbS for climate change adaptation can also have biodiversity benefits. A recent systematic map of 376 peer-reviewed studies

(Chausson et al., 2020) showed that most (73%) of the 91 cases that reported on 'ecological outcomes' showed benefits, such as an increased number of species, functional diversity, or higher plant or animal productivity (e.g. Barsoum et al., 2016; Liquete et al., 2016) with only 1% showing exclusively negative effects, and 24% reporting mixed or unclear effects. Of the cases with positive ecological outcomes, 47 were reported to also have benefits for adaptation (none were negative, four were mixed).

However, in general, few studies of NbS include explicit monitoring of biodiversity outcomes and many of the current pledges for NbS (Table 2) do not appear to recognize important distinctions. For example, FLR initiatives frame all created forests as 'forest restoration' and do not clearly distinguish reforestation from afforestation, native from non-native species or plantations from natural forests. Although the Bonn Challenge guidance encourages signatories to consider setting aside land for biodiversity, there are no quantitative targets, checks or safeguards to ensure a balance between working plantations and regeneration or restoration of natural woodlands. Perhaps due to the lack of such safeguards, an estimated 45% of Bonn Challenge pledges in tropical regions are for commercial plantations and 21% for agroforestry (Lewis, Wheeler, et al., 2019; but see Dave et al., 2019; Ghazoul et al., 2019; Guariguata et al., 2019). Commercial plantations dominate because they provide income for landowners, tax revenue for governments, jobs for local communities and fibre, food or fuel resources, which also reduces the likelihood that the forest will be illegally cleared after establishment (Dave et al., 2019; Guariguata et al., 2019). However, they are not the only type of nature-based intervention that can deliver social benefits and thereby gain local support; those that conserve and restore natural habitats can deliver win-wins for biodiversity and people (Chausson et al., 2020). Yet the imbalance in funding leaves few resources for protection or natural regeneration of diverse ecosystems (Heilmayr et al., 2020) and risks damaging biodiversity. There are concerns that low-diversity plantations of non-native species may be replacing important carbon-rich and biodiverse ecosystems including native forests (Curtis et al., 2018; Heilmayr et al., 2020; Scheidel & Work, 2018), ancient grasslands and savannahs (Bond et al., 2019; Kumar et al., 2020), heather moorland and peat bogs (Brown, 2020; Friggens et al., 2020; Sloan et al., 2018). The 'Atlas of Forest Restoration Opportunities' that supports the Bonn Challenge identifies two billion hectares of 'deforested and degraded' land as potentially suitable for tree planting (Laestadius et al., 2011, 2015; WRI, 2014) but this includes natural grasslands and savannahs that support endangered populations of large mammals (Veldman et al., 2019). Similarly, research in north-west India shows that although afforestation activities can lead to an aggregate increase in forest cover, in most cases it results in loss of diversity and promotes monocultures (Singh, 2006; Srivastava & Mehta, 2017).

Even NbS based on protecting or restoring natural habitats carry a risk that impacts (such as deforestation) could simply shift to unprotected areas to satisfy demand for food or livelihoods (Mekuria et al., 2015). Reforestation must therefore be accompanied by protection of nearby areas of intact forest, to avoid displaced deforestation (Heilmayr et al., 2020), especially as avoided deforestation offers 7.2–9.6 times as much potential low-cost climate change mitigation as reforestation overall (Busch et al., 2019).

There are cases where use of non-native species or modified species compositions may be beneficial (Harris et al., 2006); for example, if they are better adapted to current or future climates (Gray et al., 2011; Hewitt et al., 2011), if they establish more readily in harsh conditions (Yu et al., 2012) or if land is too degraded to restore to a natural state (Murcia et al., 2014; Suding et al., 2004). If non-native species are being introduced, it is important to assess and mitigate the associated risks (Sáenz-Romero et al., 2016; Simler et al., 2019; Weeks et al., 2011). Even when restoration involves only native species, there can be trade-offs that need to be managed to enhance biodiversity outcomes, as some species may benefit at the expense of others (Biel et al., 2017; Porensky et al., 2014), or species abundance could increase at the expense of species richness (Lennox et al., 2011).

In summary, NbS need to be designed explicitly to demonstrate how they will deliver measurable benefits for biodiversity. Although the optimum strategy is case-specific, and much more research is needed, a good strategy is likely to involve choosing a diverse mix of native species where possible, avoiding destruction of existing species-rich habitats, conducting initial baseline assessments, setting quantitative targets, monitoring progress and managing any unintended negative consequences (IUCN, 2020). Understanding the spatial scales and timeframes over which nature-based interventions can deliver benefits for biodiversity as well as support climate change mitigation and adaptation should be a key focus for future research.

7 | WHAT IS NEEDED NOW

7.1 | One clear voice on successful, sustainable NbS

As nations and businesses begin to incorporate NbS in their climate and biodiversity strategies, it is crucial to reach a consensus on what constitutes successful and sustainable NbS. Practitioners and decision-makers need clear and coherent principles and standardized evidence-based frameworks (Cohen-Shacham et al., 2019). This will enable NbS to be designed and implemented using the best evidence-based criteria and will allow commitments on NbS for both climate change and biodiversity to be aligned, tracked and improved over time.

To this end, we worked with a consortium of conservation and development organizations and research institutions to develop four high-level guidelines on how to develop successful NbS that avoid the pitfalls described in Section 6, which we sent to the President of the upcoming CoP26 (NbSI, 2020; Table 4). These guidelines are complementary to other normative principles

TABLE 4 Four high-level guidelines for successful, sustainable nature-based solutions agreed on by a large community of researchers and conservation and development practitioners in the UK (www.nbsguidelines.info)

Guideline	Context
Guideline 1: NbS are not a substitute for the rapid phase out of fossil fuels and must not delay urgent action to decarbonize our economies.	NbS play a vitally important role in helping to mitigate climate change this century, but their contribution is limited by a finite land area and is relatively small compared to what can be achieved by the rapid phase out of fossil fuel use. Furthermore, unless we drastically reduce GHG emissions, global heating will adversely affect the carbon balance of many ecosystems, turning them from net sinks to net sources of GHGs.
Guideline 2: NbS involve the protection and/or restoration of a wide range of naturally occurring ecosystems on land and in the sea.	All ecosystem types hold opportunities for NbS to enhance provision of ecosystem services to people. Management at the landscape scale, accounting for and utilizing interactions between ecosystems, can maximize long-term benefits. It is especially urgent to prevent inappropriate tree planting on naturally open ecosystems such as grasslands, savannahs and peatlands, or in areas with native forests. NbS must be valued in terms of the multiple benefits to people, rather than overly simplistic metrics such as numbers of trees planted.
Guideline 3: NbS are implemented with the full engagement and consent of Indigenous Peoples and local communities, including women and disadvantaged groups, and should be designed to build human capacity to adapt to climate change.	Robust social safeguards must be applied, to recognize, respect and reinforce human rights (including land/ecological and cultural rights), and support livelihoods. Just institutions will support larger scale, sustainable and more resilient NbS, at a crucial moment for the global response to climate change.
Guideline 4: NbS sustain, support or enhance biodiversity, that is, the diversity of life from the level of the gene to the level of the ecosystem.	Biodiversity plays a vital role in the healthy functioning and resilience of ecosystems. It secures the flow of essential services now and into the future, reduces trade-offs among them (e.g. between carbon storage and water supply) and helps to build human capacity to adapt to climate change in urban and rural areas.

including the WWF principles (WWF, 2020a), the World Bank principles on NbS for disaster risk reduction and water management (World Bank, 2017), the IUCN principles (Cohen-Shacham et al., 2019) which frame the IUCN Global Standard for NbS (IUCN, 2020), and the FEBA framework for EbA criteria and standards (Bertram et al., 2017). While the guidelines focus on policy guardrails for the uptake of the concept in international climate policy, the IUCN and World Bank principles frame evaluative standards for the planning and practice of NbS. The World Bank builds on five principles to delineate eight steps to guide the design, implementation, management, and monitoring and evaluation of NbS while the IUCN principles are operationalized around a set of standardized criteria that provide guidance to stakeholders and practitioners in the public, private and civil society spheres, to improve the channelling of finance towards NbS.

These principles, standards and guidelines converge on a set of key concepts, formulating a core vision to unite the NbS community. They agree on the need to support and enhance biodiversity and ecosystem integrity, and protect a range of ecosystems; and they highlight the risks of ecological simplifications, such as large-scale single-species tree planting, which can undermine the effectiveness and resilience of the intervention. They also note the need for social safeguards and for full engagement of IPLCs through co-design and co-implementation of NbS. The IUCN Global Standard also emphasize that NbS should be fair and equitable. This is a key to uphold the rights of IPLCs, increase support for the interventions, sustain the delivery of benefits, minimize social trade-offs and build adaptive capacity. However, only the WWF and NbSI guidelines are explicit that NbS are not a substitute for drastic emission reductions across sectors or an emission compensation mechanism.

The IUCN Global Standard emphasizes the need for policy coherence across sectors, to ensure NbS contribute to global targets on human wellbeing, climate change, biodiversity and human rights (IPCC, 2018). The IUCN and World Bank note the need to adopt a systems perspective for the practice of NbS. This is a key to managing trade-offs and promoting synergies between objectives and across stakeholders groups, and to identifying points of integration, or synergy with other interventions. It is also essential to account for and adaptively manage the risks to NbS, including from climate change (WWF principle 1), or poor implementation and management (WB Principle 2, IUCN standards criterion 2).

A key question is how to ensure compliance with these standards and guidelines. NbS should be subject to rigorous assessment and validation, including monitoring of multiple environmental, social and economic outcomes over the long term. However, companies have failed to comply with previous voluntary agreements (NYDF Assessment Partners, 2019), and this is likely to continue unless there is an independent regulator capable of enforcing these standards. Accountability and regulatory frameworks supported by government policy are essential to ensure NbS support transformational pathways, and this is an important area for further work.

7.2 | More holistic approaches across science, policy and practice

A more holistic approach to NbS is needed to maximize their potential benefits while balancing trade-offs. Capturing the full range of benefits arising from nature can incentivize additional investment, while managing trade-offs between benefits and among different sectors of society can channel this investment more effectively. Here we summarize the key elements of a holistic approach: (1) participatory design and implementation using different forms of knowledge; (2) a landscape approach that considers a wide range of connected habitats and the effects that interventions in one habitat or area have on others; (3) evaluating and managing the full range of benefits, trade-offs and conflicts across landscapes and societies and (4) implementing NbS as part of an integrated sustainability strategy across sectors.

First, as discussed in Sections 3.2 and 6.2, NbS should be co-designed and co-implemented through an equitable participatory process involving IPLCs, other stakeholders and researchers. This should bring together different forms of knowledge in a transdisciplinary and cross-sectoral approach, giving indigenous and local knowledge due representation (Chazdon, 2020; Lavorel et al., 2019; Meselhe et al., 2020). Researchers and research-users should agree on research aims and co-produce the evidence base needed to support well-designed NbS (Hoffmann et al., 2019; Knapp et al., 2019), and researchers must communicate their findings in clear, policy-relevant ways (Neßhöver et al., 2013). Genuine collaboration between researchers and research users increases the legitimacy, ownership and accountability of the solutions (Mauser et al., 2013).

Second, NbS should be integrated into a multifunctional landscape (Kremen & Merenlender, 2018) or seascape approach that takes account of the interconnections between habitats and the needs of different beneficiaries. On land, depending on the local context, this might include a balanced mix of habitats, including sustainably managed working forests and farmland together with wetlands, grasslands, native forest, heath and scrub. A diversity of land uses supports a diversity of livelihoods and thereby provides more security of income during times of environmental or socio-economic stress. Spatial planning can target the right land use in the right place. For example, the most biodiverse habitats could be integrated into a connected network that allows animal and plant species to shift their ranges in response to climate change (Brancalion & Chazdon, 2017; Lavorel et al., 2020). Sustainable agriculture and agroforestry could be prioritized on the most productive land while hydrological models could identify the optimum areas for new native woodland to reduce flood and erosion risk, avoiding naturally open habitats and organic soils. Where plantations are needed to meet demand for wood products, more sustainable forest management practices could reduce their adverse impacts, such as planting a mix of native species (which can be more productive than a monoculture), lengthening rotation times (Law et al., 2018), leaving strips of native vegetation and practising selective logging rather than clear-felling (Griscom, & Cortez, 2013; Hartley, 2002; Putz et al., 2012). In the marine context, planning of NbS needs to take into account the interdependencies between habitats. For example, the storm protection service of an interconnected reef–seagrass–mangrove seascape is greater than for a single coastal habitat on its own (Barbier & Lee, 2014; Sanchirico & Springborn, 2011).

Third, it is important to evaluate the full range of potential benefits, as well as actively identifying, managing and mitigating trade-offs and conflicts in an equitable way. Focusing on a narrow range of benefits, such as carbon sequestration or timber production, can lead to avoidable adverse impacts such as biodiversity loss or water scarcity. Currently, few of the studies reporting adaptation outcomes of NbS also consider mitigation and broader social outcomes, and biodiversity outcomes in particular are often only implied or rudimentarily studied (Chausson et al., 2020). Robust monitoring and evaluation of the multiple benefits of NbS across landscapes and societies demand a transdisciplinary approach to research that can capture environmental, economic and social impacts (Hoffmann et al., 2019; Scholz & Steiner, 2015) and this must be tailored to local value systems and perspectives (Sterling et al., 2017). Integrated valuation can promote more equitable and inclusive governance of NbS (Liquete et al., 2016; Pascual et al., 2017); scenario analyses can help to identify policies that minimize trade-offs (Metzger et al., 2017) and quantification of trade-offs can be used support participatory approaches for dealing with conflicts (King et al., 2015).

Finally, NbS should form part of an integrated sustainability strategy across sectors. They should not be seen as an alternative to technological solutions and must not be framed as a 'fix all' solution. We need both nature-based and technological approaches to many of the challenges we face. For example, to build coastal resilience often requires a combination of nature-based and man-made flood defences (Vuik et al., 2016); to restore landscapes, mixing in productive 'nursery trees' for selective logging can provide an income source while native species regenerate (Amazonas et al., 2018; Brancalion et al., 2020). We have discussed how NbS must be accompanied by rapid reductions in fossil fuel emissions. And, critically, NbS will work best in the framework of a green and circular economy. Shifting to a circular economy with less waste, a more plant-based diet and less over-consumption of resources would free up land for carbon storage and biodiversity (Chaudhary et al., 2017; Poore & Nemecek, 2018; Strassburg et al., 2020). For example, more re-use and recycling of wood products would reduce the demand for wood from plantations and allow rotation lengths to be increased, with benefits for carbon sequestration (Hudiburg et al., 2019). Similarly, reducing energy demand and associated CO_2 emissions (such as in pathway 1 of the IPCC 1.5°C report) almost eliminates the need to use BECCS and afforestation as CO_2 removal mechanisms, while continued high energy demand (pathway 4) results in a huge overshoot of emissions followed by extensive use of BECCS, which would have major adverse impacts on biodiversity and food security (IPCC, 2018).

A holistic approach should inform the development of robust and explicit policy targets aligned across the UNFCCC, CBD and SDGs (Milbank et al., 2018; Panfil & Harvey, 2016). Together with baseline assessments and better monitoring of NbS outcomes, explicit targets can help to ensure multiple benefits for biodiversity (Chatzimentor et al., 2020; Xie & Bulkeley, 2020), social equity, climate and other goals.

7.3 | Mobilizing and targeting finance for sustainable NbS

There is a huge funding gap in investments in nature: for preserving and restoring ecosystems alone, the required investment is estimated at US$300–400 billion per year, whereas only US$52 billion is being invested annually in such projects (WWF, 2020b). While an increase in public funding would help plug some of the gap, it is clear that there needs to be a substantial hike in investment flowing to NbS from the private sector (WWF, 2020b). As outlined in Section 4.3, there have been dozens of funding pledges for NbS. While such commitments may indicate a shift in the private sector, the scale and nature of this funding remains problematic for a number of reasons. First, most private commitments to NbS are framed as offsets, which often involve greenwashing (Section 6.1), and there is a focus on tree-planting programmes (Section 6.2), often imposed in a top-down manner, that can result in adverse impacts for local people (Section 6.3) and biodiversity (Section 6.4). Second, it is difficult to determine what actions companies or banks are taking as few of those with pledges for nature define clear and actionable plans for implementing and verifying commitments (Addison et al., 2019; Rogerson, 2019). Third, even if companies and banks invest in ecologically and socially sound projects, the investments are not large enough to match the scale of their dependencies on nature (WEF, 2020b).

To address these issues, a system needs to be in place to restrict verification of the benefits of investment in NbS as a carbon offset to those entities that meet stringent criteria for ambitious and verifiable emissions reductions through their operations and supply chains (Section 6.1). In addition, companies and banks should adopt standards for monitoring and evaluation of NbS, such as the IUCN Global Standard for NbS and the upcoming revision of the UN's System of Environmental Economic Accounting (SEEA); together, these can facilitate accounting and help ensure the quality of NbS, including encouraging the funding of multiple types of actions beyond tree planting (Section 7.1).

Since much of the funding currently available for NbS requires documented increases in carbon stocks, there is also much need for improved quantification of the GHG stocks and fluxes of a greater diversity of habitats, moving beyond the current metrics for tree planting and peatland restoration. By combining these data with high-quality information on biodiversity and the value of ecosystems for local communities, we can develop more granular metrics for assessing and verifying the return on NbS investments over time. Such metrics, together with a robust typology that clarifies the benefits and trade-offs of different NbS options for different social groups, will allow investors to identify appropriate projects, and help NbS practitioners identify willing funders. Formation of intermediary bodies which help link good investors with high-quality NbS projects (Freireich & Fulton, 2009) can also facilitate the transition to large-scale funding of successful, sustainable NbS.

Businesses have a critical role to play in creating a sustainable world where nature and people thrive together, but funding NbS is only one part of this role—fundamental changes in the functioning of businesses and the economy more broadly are also urgently needed. Governments can incentivize the sustainable management of resources through measures such as carbon and resource taxes, and regulation to reduce environmental externalities such as pollution while providing financial support for sustainable investments. Companies must adopt regenerative and circular economy models, and must appropriately embed natural capital into accounting procedures (Reed et al., 2007). Natural capital accounting aims to measure the extent and condition of ecosystems and their potential to provide services in years to come, not just the current flow of services, to ensure that natural capital stocks are not depleted by over-exploitation and habitat degradation. An important step towards natural capital accounting becoming the norm was the creation of a Task Force on Nature-related Financial Disclosures (TNFD) by a partnership involving Global Canopy, the United Nations Development Programme, the United Nations Environment Programme Finance Initiative and the World Wide Fund for Nature. Working with financial institutions, private firms, governments and regulatory bodies, think tanks and consortia, the TNFD will publish guidelines on measuring and reporting dependences and impacts on nature (TNFD, 2020). Blended public–private finance can also support NbS, where governments underwrite the risk to companies of investing in unproven technologies. Achieving the transition to a sustainable economy will require unprecedented collaboration between private and public sector actors, economists, and NbS researchers and practitioners.

8 | CONCLUSION

Nature-based solutions emerged from the major paradigm shift that took place in the late 2000s, that involved a move away from conserving nature for its own sake to conserving nature for people's sake, and from 'regarding people as passive beneficiaries of nature to active protectors and restorers' (Mace, 2014). A decade later, NbS could play a key role in enabling another and even more fundamental paradigm shift that is being 'fast-tracked' by the current coronavirus pandemic. This is the transformation of a destructive global economic model centred around GDP and infinite growth, that ignores nature's value to people and its intrinsic value, to one where a healthy economy is defined by the social and ecological well-being it brings (Raworth, 2017). For NbS to support this transformation, it is vital to get the message right about what the concept of NbS comprises. Successful NbS are co-designed and implemented with local communities, to optimize the equitable delivery of multiple benefits and manage undesirable trade-offs. They are biodiversity-based and explicitly designed to deliver biodiversity benefits, and occur as part of a holistic framework of sustainability policies including the rapid phase out of fossil fuels. For NbS to be part of a 'just transition', we need to challenge the structural features and inequities of human society which drive biodiversity loss and climate change, and hold companies and governments to account for the environmental and social damage they cause or permit. To implement NbS at scale and avoid simply displacing environmental impacts, land must be freed up from other uses, through a shift towards plant-based diets and widespread adoption of a circular economy to reduce demand for raw materials. By following these guidelines, we can design robust and resilient NbS that address the urgent challenges of climate breakdown and biodiversity loss, sustaining nature and people together both now and into the future.

ACKNOWLEDGEMENTS

This study was supported by a Natural Environmental Research Council Knowledge Exchange Fellowship to N. Seddon (NE/R002649/1), with additional funding from the University of Oxford (John Fell Fund and Oxford Martin School). The article also draws on research conducted by S. Srivastava under ESRC STEPS Centre project (ES/I021620/1) and the TAPESTRY project, which is supported by Belmont Forum and NORFACE Joint Research Programme on Transformations to Sustainability (grant agreement No 730211). We also thank Stephen Woroniecki for his help with Figure 1, and for comments on the manuscript. Finally, we are most grateful to Robin Chazdon, Beatriz Luz and an anonymous reviewer for comments that helped to improve this paper.

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analysed or analysed during the current study.

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How to cite this article: Seddon N, Smith A, Smith P, et al. Getting the message right on nature-based solutions to climate change. *Glob Change Biol*. 2021;00:1–29. https://doi.org/10.1111/gcb.15513