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Natural Climate Solutions must embrace multiple perspectives to ensure synergy with sustainable development

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To limit global warming to well below 2°C, immediate emissions reductions must be coupled with active removal of greenhouse gases from the atmosphere. "Natural Climate Solutions" (NCS) achieve atmospheric CO_2 reduction through the conservation, restoration, or altered management of natural ecosystems, with enormous potential to deliver "win-win-win" outcomes for climate, nature and society. Yet the supply of high-quality NCS projects does not meet market demand, and projects already underway often fail to deliver their promised benefits, due to a complex set of interacting ecological, social, and financial constraints. How can these cross-sectoral challenges be surmounted? Here we draw from expert elicitation surveys and workshops with professionals across the ecological, sociological, and economic sciences, evaluating differing perspectives on NCS, and suggesting how these might be integrated to address urgent environmental challenges. We demonstrate that funders" perceptions of operational, political, and regulatory risk strongly shape the kinds of NCS projects that are implemented, and the locations where they occur. Because of this, greenhouse gas removal through NCS may fall far short of technical potential. Moreover, socioecological co-benefits of NCS are unlikely to be realized unless the local communities engaged with these projects are granted ownership over implementation and outcomes.

KEYWORDS

Natural Climate Solutions, reforestation, green finance, indigenous peoples and local communities (IPLCs), expert elicitation

Introduction

The IPCC's latest assessment report acknowledged that stabilizing the planet's climate will require not only sharp decreases in current rates of greenhouse gas emissions, but also "negative emissions" – i.e. capture and removal of greenhouse gases from the atmosphere (IPCC, 2022). There are a variety of negative emissions technologies under study, but at the present time reforestation/afforestation is the most efficient and scalable option (Griscom et al., 2017, 2019). Forestry-based NCS drive atmospheric CO_2 removal through the natural processes of photosynthesis and soil carbon sequestration, with the potential to support human wellbeing and other environmental benefits, e.g., biodiversity conservation. The

potential ecological and social co-benefits of NCS drive their appeal to policy makers, funders, and the general public, leading to an explosion of interest in ecosystem restoration (Seddon, 2022). Yet despite the recent commitment[1] from 145 countries to strengthen forest conservation (IPCC, 2022) as well as private-sector commitments to restore millions of hectares of forest habitat (Sacco et al., 2021), rates of forest loss have recently increased across parts of Europe (Ceccherini et al., 2020) and frica, and deforestation continues in South merica (F O and UNEP, 2020). What might account for this disconnect?

Implementing NCS projects at scale involves complex negotiations among multiple stakeholders and sectors: the communities whose livelihoods depend on carbon-rich ecosystems; participants in voluntary carbon markets; corporates seeking action on net zero commitments; and the policy makers who must balance these stakeholders" various needs. In this article, we focus specifically on how environmental scientists, local stakeholders, and project funders perceive the benefits and risks of NCS projects. To examine the discourse between the "supply" and "demand" sides of emerging NCS markets, as well as those developing regulatory frameworks to shape the markets, we conducted an elicitation of 17 recognized experts in the areas of ecology, finance, and climate policy, and social science. We also held a virtual workshop with representatives from an additional 17 organizations including environmental charities, policy think tanks, environmental research centers, financial institutions, and large corporations with a stake in the NCS sector. Below, we outline the findings that have emerged from this dialogue, as well as the recent surge of research into forest landscape restoration and its social, economic, and environmental drivers.

What does society want from Natural Climate Solutions?

The main goal of NCS is to reduce net CO_2 emissions to the atmosphere by enhancing carbon sequestration in natural ecosystems. However, the perceived ecological co-benefits of NCS are part and parcel of their appeal to policy makers, funders, and the general public. Habitat loss remains the primary driver of biodiversity decline, and both conservation and ecosystem restoration are necessary to avert mass extinction (Banks-Leite et al., 2020). NCS can address both the climate and biodiversity crises by establishing resilient ecosystems that simultaneously absorb carbon and provide space for wildlife. Yet enthusiasm for NCS belies widespread apprehension within the environmental science community about unintended consequences of large-scale habitat transformation (Seddon et al., 2021). The nature of these risks depends upon the ecosystem being modified. lthough mangroves, seagrass beds, and peatlands can all sequester large amounts of carbon, here we will align our focus with the current emphasis on reforestation and afforestation projects, which have the largest CO_2 removal potential (Griscom et al., 2017) and are currently the most popular (Seddon et al., 2019).

n expert elicitation survey (Figure 1) identified broad consensus about two key concerns surrounding forest-based NCS projects: replacement of biodiversity-rich habitat with "carbon plantations," and increased vulnerability of forest carbon to future disturbance. Planting trees can harm biodiversity when intact forests are replaced with fast-growing tree monocultures (Lewis et al., 2019; Seddon et al., 2020), or when trees are established in inappropriate locations, such as savannahs or peatlands (Veldman, 2019; Fleischman et al., 2020). Low species diversity, homogenous canopy structure, and inappropriate planting location also elevate the risk that any carbon sequestered in forests will be lost again to disturbance, particularly wildfires, floods, or droughts (Waring et al., 2020). These global change drivers are increasingly threatening already mature forests (nderegg et al., 2020), transforming ecosystems that were historically carbon sinks into carbon sources (Gatti et al., 2021). To mitigate such risks, ecologists recommend that NCS projects include a full spectrum of conservation *and* restoration activities, protecting carbon-rich habitats where they already exist, allowing ecosystem regeneration to occur naturally where possible, and planting diverse, native tree species only when required (Sacco et al., 2021; Seddon et al., 2021).

NCS projects can also address sustainable development goals and empower indigenous peoples and local communities (IPLCs). Targeted habitat restoration can reduce the impacts of climate driven droughts or floods, buffer income streams against unpredictable yields, and augment people's participation in local governance through community-based resource management (Seddon et al., 2020). The engagement of local communities with NCS projects often enhances their environmental outcomes too. For example, forests managed by indigenous peoples or local communities often have lower rates of degradation than formally protected forests (Porter-Bolland et al., 2012; lejo et al., 2021). Local communities also play an instrumental role in forest creation: in Tanzania, for instance, smallholder farmers have planted as many trees as corporations and national governments operating in the same areas (Kimambo, 2020). Community-led forestry programmes often struggle to access finance and to receive support from central governments (Wardell, 2021), raising the demand for innovative financial instruments that can channel public and private-sector finance to local communities.

How are NCS projects developed in practice?

Critical decisions related to the implementation of NCS projects—where they are located, the restoration techniques used, and how outcomes are quantified—are all linked to the source of finance. NCS projects may be funded through a variety of mechanisms: financial market instruments (e.g., green bonds), nature market instruments (e.g., carbon credits), or via the public purse through government initiatives. Our expert elicitation (Figure 1B) revealed a strong support for direct compensation

1 https://ukcop26.org/glasgow-leaders-declaration-on-forests-and-land-use/

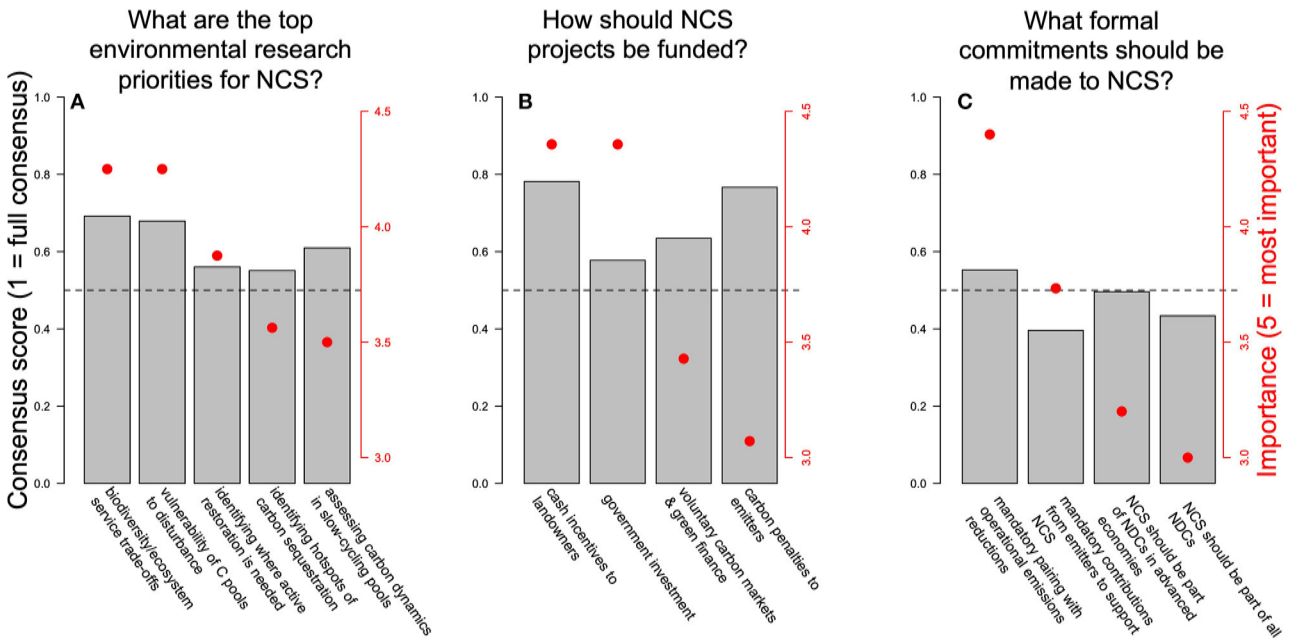

FIGURE 1
Expert elicitation results answering three questions. ( ) What are the top environmental research priorities for NCS? **(B)** How should NCS projects be funded? **(C)** What formal commitments should be made to NCS? We conducted an expert elicitation to gauge consensus on issues relating to NCS projects. Barplots show consensus scores, generated from Likert survey data. consensus score of 1 would indicate that all respondents (*N* 16, for our survey) chose the same Likert response category, while a consensus score of 0 would indicate that responses were equally divided between opposing categories (e.g., "strongly agree" vs. "strongly disagree"). Scores falling below the dashed line indicate more disagreement than consensus among the respondents. The red points in each figure indicate the arithmetic mean of all responses, reported on a 1–5 scale, with 5 indicating "most important" or "strongly agree" (Tastle and Wierman, 2007). Thus, higher values indicate greater perceived importance of the corresponding category.

to landholders, with the role of voluntary carbon markets de-emphasized, and dissention about the role of government support in NCS schemes. Public and private-sector funders have different approaches to cost minimization, varied expectations of return on investment, and perception of key risks. These considerations, in turn, determine whether and how NCS projects deliver their intended benefits.

Financing NCS: how the source of funding shapes project implementation

Some NCS project funders may expect a financial return on their initial investment, which means the performance of an asset (e.g., a carbon credit) must be tracked over time. There are relatively mature markets centered on the trading of carbon credits, but valuation of other ecosystem services (e.g., biodiversity) is much more challenging. nd even for projects centered on carbon removal, the monitoring, reporting, and verification (MRV) of project assets can be a complicated task (United Nations Development Programme, 2019). ll protocols aimed at quantifying carbon sequestration through ecosystem restoration share a common goal: ensuring CO_2 removal from the atmosphere is additional and permanent, while avoiding leakage effects (whereby restoration of habitat in one area indirectly drives habitat loss elsewhere). Meeting this goal depends upon clear project baselines to establish what would have happened in absence of the intervention, and sequestration of carbon in pools that are easy to measure at large spatial scales. Yet there is no universal standard for MRV of NCS projects. Various greenhouse gas crediting programmes recommend slightly different methodologies for MRV, but all have their flaws and many lack rigor, especially for carbon sequestration in non-woody biomass (e.g., soils) (Zelikova et al., 2021). Recent investigations revealed that while NCS operations adhering to voluntary carbon standards do produce measurable reductions in forest loss (Guizar-Coutiño et al., 2022), these projects often dramatically over-state (and by implication, over-sell) the carbon benefits of their interventions (West et al., 2020). Moreover, there is debate about permanence, or how long NCS projects must be maintained in order to address climate goals. lthough short-term CO_2 removals might be helpful in limiting peak warming (Matthews et al., 2022), ecological co-benefits could be strongly constrained if restored habitats do not persist in the landscape. Finally, key to meeting climate targets, conservation of intact forests avoids emissions from deforestation in the first place. However, quantifying the emissions reduction from avoided deforestation projects is highly dependent on the assumed fate of the forest stand in the absence of the project-that is, the "counterfactual baseline". Because this is a hypothetical baseline, different methods used to construct it can lead to very different results, creating opportunities for errors or even gaming the system (Costanza et al., 2014).

Funders' expectation of return on investment also affects how the social or environmental co-benefits of NCS projects are defined,

prioritized, measured and, ultimately, pursued. The complexities of quantifying and valuing biodiversity are emblematic of these challenges. Governments and businesses now acknowledge that the global economy is entirely dependent upon the services provided by nature (Costanza et al., 1997, 2014; Dronamraju, 2021). However, although global trends clearly indicate that biodiversity is being lost at unprecedented rates (Rockström et al., 2009), it is much more difficult to detect and document changes in biodiversity at local scales. In part, this difficulty stems from the multiple meanings of "biodiversity," which encompasses not only the number of species present within a given area, but also the abundance of each species, their genetic and functional characteristics, and their complex interactions with one another (Noss, 1990). s a result, we lack a single operational metric of biodiversity (Turnhout, 2020), which in turn complicates efforts to measure it. There is a major effort underway to develop a harmonized biodiversity MRV protocol which corporates can adopt (CISL, 2020), but there are still major difficulties ascribing a tangible economic value to changes in biodiversity. Moreover, the concept of a biodiversity credit implies that biodiversity gain in one locale can "offset" its loss elsewhere, which is an ethically fraught concept. Thus, the "biodiversity credit" market is only in its infancy.

Expected return on financial investment can shape NCS project implementation on the ground. Whereas, environmental scientists highlight the need to balance conservation, natural regeneration, and active restoration (e.g., tree planting), many funders are wary of projects with complex MRV and opaque return on investment. s a result, forestry-based NCS projects largely employ active restoration, such that increases in ecosystem carbon stocks (and their associated revenue) can be measured easily. For example, much of the forest restoration pledged under the Bonn Challenge (to restore 350 Mha across 43 countries) consists of commercial tree plantations (Lewis et al., 2019), and most NCS project goals are framed in terms of "number of trees planted" rather than "area of forest restored" (Holl, 2020). In other words, linking project finance to a return on investment incentivizes exactly the type of large-scale tree planting projects that ecologists have specifically warned against (Fleischman et al., 2020).

Perceptions of operational, political, and reputational risk affect decision making

The capacity of NCS projects to meet environmental and social targets also depends upon how funders perceive risks associated with project implementation and outcomes. Project funders assume operational risk (e.g., that planted trees will fail to survive and grow); political/governance risk (e.g., that land tenure is not secure); and reputational risk (e.g., perceptions of "greenwashing"). Each type of risk affects decision making processes in different ways. For example, the risk of restoration failure is difficult to quantify, but may be substantial. In the tropics, where most forestry-related projects are located, fewer than 5% of tree planting organizations monitor seedling survival (Martin et al., 2021). However, the mortality of tree seedlings can be very high, and direct interventions (such as tree planting) are often less successful than natural ecosystem regeneration processes in restoring forest cover (Crouzeilles et al., 2017). The last decade has seen some high-profile project failures, such as the death of over 90%[2] of seedlings in Turkey's record-breaking tree planting campaign. However, our workshop revealed that funders do not perceive these operational risks as the major barrier to implementation; rather, there is more of a focus on reputational risk. This is a major concern both of private-sector funders, whose engagement with NCS projects are inextricably linked with corporate identity; and with organizations that execute NCS projects, which are competing in an exponentially growing market of restoration providers. Organizations which make overly glib promises about their capacity to scale ecosystem restoration have recently come under heavy scrutiny (Castro et al., 2022). The recent controversy[3] over project baselines in avoided deforestation scenarios illustrates how the technical nuances of NCS might increase risk-return perceptions by investors.

Funders also perceive significant risks related to land tenure and local governance mechanisms that determine access to land. For example, cessation of land use does not imply cessation of land rights; land classified as "abandoned" and therefore suitable for reforestation may, in fact, have a legal owner who wishes to recommence agricultural use at a later date (Holl et al., 2022). Indigenous communities' rights to the land they occupy are often not formally recognized (Haenssgen et al., 2022), undermining their ability to continue protecting their land and to receive financial support for doing so. NCS projects funders may therefore seek to negotiate directly with central governments to ensure land rights are legal and enforceable, and to facilitate the free, prior, and informed consent (FPIC) of IPLCs who manage the land. However, because land tenure is often so complex, even projects conducted with due legal diligence may harm local communities with customary but informal rights to land, as vividly exemplified by a case study in Uganda (Richards, 2016). There, a Norwegian company acquired land rights from the Ugandan government to establish forest plantations and generate carbon credits. In the process, the company evicted local villagers who had used the land for grazing and subsistence crops, threatening their survival. In other areas, there is encouraging evidence that the vital role of IPLCs in NCS is receiving increasing recognition. For example, in the Philippines, recent review of the central government's reforestation scheme recommended that future programme activities should be undertaken only in collaboration with community-based forestry organizations (Wardell, 2021). Cognizant of the complex environmental and social context of forest restoration, though, some companies are choosing to develop net zero strategies that rely on other, more speculative negative emissions technologies, such as direct air capture. For example, EasyJet recently abandoned[4] its carbon offsetting programme in favor of research into greener aviation fuel.

2 https://www.theguardian.com/world/2020/jan/30/most-of-11m-trees-planted-in-turkish-project-may-be-dead

3 https://www.theguardian.com/environment/2023/jan/18/revealed-forest-carbon-offsets-biggest-provider-worthless-verra-aoe

4 https://www.ft.com/content/e541240f-1ff6-46d0-917d-aee3d02f302b

Key obstacles to the success of NCS

Participants in our workshop articulated a central challenge for NCS: it is difficult to take into account the social and environmental nuances that drive project success, while operating at the speed and scale necessary to mitigate climate change through reforestation. lthough project funders express great willingness to engage directly with IPLCs and support local economies through NCS projects, it is often difficult to identify the legal and financial mechanisms that would permit them to do so. For example, how might those with customary (but not legal) rights to land be incentivized to support its reforestation? What incentive structures might be used when local communities largely do not engage with a cash-based economy? These problems are thorny and difficult to solve without a nuanced understanding of the local context of each NCS project. This is one reason that major forestry-based commitments through public and private sectors (e.g., Bonn Challenge, Trillion Trees) have made relatively slow progress in recent years, despite significant public enthusiasm for forest restoration. Recent revelations about the failures or shortcomings of NCS projects (West et al., 2020) stoke fears that forestry-based carbon credits may become a "toxic asset" (I TP, 2009), further imperiling efforts to conserve and restore vital habitats.

For NCS to succeed in delivering environmental and social benefits, more work needs to be done to link the organizations that wish to invest in NCS with the local stakeholders who will be most directly impacted by project successes and failures. Currently, NCS projects receive two major sources of financial support: private funding through voluntary carbon markets, and public funding through national governments. The voluntary carbon market has quadrupled in size since 2020 (Donofrio et al., 2022), and much of this capital is flowing into reforestation/afforestation projects. Projects funded via this mechanism are expected to produce a financial return (i.e. initial project investment can be recouped through the sale of valuable carbon credits), leading many to prioritize single asset classes, such as carbon. By contrast, governments nominally control the majority of the world's forests (White and Martin, 2002), and are poised to develop a diverse portfolio of NCS projects that balance multiple national priorities including climate mitigation, biodiversity conservation, and sustainable economic development. However, in the developing countries where NCS projects tend play a more prominent role in nationally determined contributions (NDCs) to the Paris greement, external sources of finance would be required to support project development (Seddon et al., 2019). In the past, such finance transer schemes have been criticized for channeling funds to corrupt governments rather than the actual stewards of the land, and for failing to deliver the co-benefits that would incentivise long-term participation by local communities (Lawlor and Weinthal, 2010). Injecting capital from governments and corporations into NCS projects can also place local communities at risk, strengthening central government control over territories traditionally administered by indigenous or local peoples (Milne et al., 2019). Such scenarios have fuelled strong critiques of the "financialisation" of land and the assets associated with it (Knuth, 2015), unintentionally transforming NCS project backers into "green grabbers" who transfer ownership and use of land from local communities to the powerful institutions of the global North (Corson, 2012). This may explain why there is significant dissention, even among experts (Figure 1C), about the role of formal government commitments in advancing NCS projects.

Outlook

Despite the complexities involved in implementing environmentally and socially responsible ecosystem restoration, there is reason to be optimistic about the future of NCS. New financial instruments that blend private and public finance, together with "jurisdictional" approaches that allow locally operated projects to be nested within national monitoring frameworks, can maximize the efficacy of NCS across scales (Köberle et al., 2021). Moreover, because the key role of local stakeholders in NCS projects is universally acknowledged (Chazdon, 2019; Seddon et al., 2020; Seddon, 2022), we can look to existing models of community forestry to identify what drives their success in maintaining forest cover and supporting local livelihoods. Forestry programmes with good outcomes tend to share a number of common factors: they have robust internal governance, as well as support from regional and national governments; they operate in environments where land tenure is secure; they provide material benefits for local communities; and they allow for the full participation of women and those across a spectrum of socioeconomic groups (Baynes et al., 2015). These factors should be considered necessary components of the enabling environment which allows NCS projects to be effective. t the same time, new tools are being developed to help evaluate land tenure rights and local governance in relation to proposed habitat restoration initiatives (McLain et al., 2021). Recently developed "green taxonomies" can help identify projects that are at risk of creating perverse incentives, putting human rights at risk, or failing to engage local stakeholders in the long term.

There will always be a tension between the careful, nuanced, site-specific approaches that enable sustained forest recovery in particular locales, vs. the accelerated speed and global scale of solutions demanded by the climate crisis. The absence of a "one size fits all" approach to NCS poses a challenge for upscaling solutions. However, it also means that progress can be made through many complementary avenues—via local (Baynes et al., 2015) and commercial (Forster et al., 2021) forestry operations; through indigenous communities or regional governments; and through collaborations among ecologists, economists, and sociologists. Yet all emission reductions and related co-benefits claimed by NCS projects, wherever and however they are implemented, must be credible and verifiable. This will ensure the sustainability of financial flows that will enable NCS projects to achieve the required scale. Projects that can demonstrate such integrity may incur higher costs, so investors need to be prepared to pay more for each carbon credit acquired (Köberle et al., 2021). lthough some NCS projects may require significant initial investment, they are still cost-effective when valued with an appropriately

inclusive framework: restored ecosystems buffer climate, disease, and pollution risks, in addition to mitigating climate change (Seddon et al., 2020). Most critically, successful NCS depend upon an open dialogue and shared costs and benefits among those who fund, implement, and benefit from these projects, which cannot be successful without the support of the communities living and working closest to them.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

uthor contributions

BW led the research and writing of the paper. ll authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

lejo, C., Meyer, C., Walker, W. S., Gorelik, S. R., Josse, C., ragon-Osejo, J. L., et al. (2021). re indigenous territories effective natural climate solutions? neotropical analysis using matching methods and geographic discontinuity designs. *PLoS ONE* 16, e0245110. doi: 10.1371/journal.pone.0245110

nderegg, W. R., Trugman, . T., Badgley, G., nderson, C. M., Bartuska, ., Ciais, P., et al. (2020). Climate-driven risks to the climate mitigation potential of forests. *Science*. 368, eaaz705. doi: 10.1126/science.aaz7005

Banks-Leite, C., Ewers, R. M., and Folkard-Tapp, H. (2020). Countering the effects of habitat loss, fragmentation, and degradation through habitat restoration. *One Earth* 3, 672–676. doi: 10.1016/j.oneear.2020.11.016

Baynes, J., Herbohn, J., Smith, C., and Fisher, R. (2015). Key factors which influence the success of community forestry in developing countries. *Glob. Environ. Chang.* 35, 226–238. doi: 10.1016/j.gloenvcha.2015.09.011

Castro, J., Morales-Rueda, F., lcaraz-Segura, D., and Tabik, S. (2022). Forest restoration is more than firing seeds from a drone. *Restor. Ecol.* 45, 2–5. doi: 10.1111/rec.13736

Ceccherini, G., Duveiller, G., Grassi, G., Lemoine, G., vitabile, V., Pilli, R., et al. (2020). brupt increase in harvested forest area over Europe after 2015. *Nature* 583, 72–77. doi: 10.1038/s41586-020-2438-y

Chazdon, R. (2019). Restoring forests as a means to many ends: an urgent need to replenish tree canopy cover calls for holistic approaches. *Science* 364, 24–25. doi: 10.1126/science.aax9539

CISL (2020). *Measuring Business Impacts on Nature Framework to Support Better Stewardship of Biodiversity in Global Supply Chains*. Oakland, C : C M Publishing (2020).

Corson, C. (2012). Enclosing the global commons: the convention on biological diversity and green grabbing. *J. Peasant Stud.* 39, 263–283. doi: 10.1080/03066150.2012.664138

Costanza, R., d' rge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., et al. (1997). The value of the world's ecosystem services and natural capital. Nature 387, 253–60.

Costanza, R., Groot, D., Sutton, R., Van der Ploeg, P., nderson, S., Kubiszewski, S. J., et al. (2014). The global value of ecosystem services. *Glob. Environ. Chang.* 26, 152–158. doi: 10.1016/j.gloenvcha.2014.04.002

Crouzeilles, R., Ferreira, M. S., Chazdon, R. L., Lindenmayer, D. B., Sansevero, J. B., Monteiro, L., et al. (2017). Ecological restoration success is higher for natural regeneration than for active restoration in tropical forests. *Sci. dv.* 3, 1–8. doi: 10.1126/sciadv.1701345

Donofrio, S. M., Patrick-Daley, C. C., and Ciro-Lin, K. (2022). *The art of integrity: State of the Voluntary Carbon Markets 2022 Q3 Insight Briefing. Forest Trends' Ecosystem Marketplace*. Washington, DC: Forest Trends ssociation.

Dronamraju, K. R. (2021). The economics of biodiversity: the dasgupta review. Headline messages. *Biol. Wealth Other Essays*. 126–145.

F O and UNEP (2020). *The State of the World's Forests 2020*. Rome: F O and UNEP.

Fleischman, F., Basant, S., Chhatre, ., Coleman, E. ., Fischer, H. W., Gupta, D., et al. (2020). Pitfalls of tree planting show why we need people-centered natural climate solutions. *Bioscience* 70, 947–950. doi: 10.1093/biosci/biaa094

Forster, E. J., Healey, J. R., Dymond, C., and Styles, D. (2021). Commercial afforestation can deliver effective climate change mitigation under multiple decarbonisation pathways. *Nat. Commun.* 12, 1–12. doi: 10.1038/s41467-021-24084-x

Gatti, L. V., Basso, L. S., Miller, J. B., Gloor, M., Gatti Domingues, L., Cassol, H. L., et al. (2021). mazonia as a carbon source linked to deforestation and climate change. *Nature* 595, 388–393. doi: 10.1038/s41586-021-03629-6

Griscom, B. W., dams, J., Ellis, P. W., and Houghton, R. . (2017). Natural climate solutions. *Proc. Natl. cad. Sci.* 114, 11645–11650. doi: 10.1073/pnas.1710465114

Griscom, B. W., Lomax, G., Kroeger, T., Fargione, J. E., dams, J., lmond, L., et al. (2019). We need both natural and energy solutions to stabilize our climate. *Glob. Chang. Biol.* 25, 1889–1890. doi: 10.1111/gcb.14612

Guizar-Coutiño, ., Jones, J. P., Balmford, ., Carmenta, R., and Coomes, D. . (2022). global evaluation of the effectiveness of voluntary REDD+ projects at reducing deforestation and degradation in the moist tropics. *Conservation Biol.* 36, e13970. doi: 10.1111/cobi.13970

Haenssgen, M. J., Lechner, . M., Rakotonarivo, S., Leepreecha, P., Sakboon, M., Chu, T. W. (2022). Implementation of the COP26 declaration to halt forest loss must safeguard and include Indigenous people. *Nat. Ecol. Evol.* 6, 235–36. doi: 10.1038/s41559-021-01650-6

Holl, K. D. (2020). Tree planting is not a simple solution. *Science* 368, 580–581. doi: 10.1126/science.aba8232

Holl, K. D., shton, M. S., Bukoski, J. J., Culbertson, K. ., Curran, S. R., Harris, T. B., et al. (2022). Redefining "abandoned" agricultural land in the context of reforestation. *Front. For. Glob. Chang.* 5, 1–6. doi: 10.3389/ffgc.2022.933887

I TP (2009). Speculating on Carbon: The Next Toxic sset. Washington, DC: I TP.

IPCC (2022). *Summary for Policy Makers: Working Group III contribution to the Sixth ssessment Report of the Intergovernmental Panel on Climate Change. Climate Change 2022: Mitigation of Climate Change.*

Kimambo, N. E. (2020). The role of smallholder woodlots in global restoration pledges–Lessons from Tanzania. *For. Policy Econ.* 115, 102144. doi: 10.1016/j.forpol.2020.102144

Knuth, S. E. (2015). Global finance and the land grab: mapping twenty-first century strategies. *Can. J. Dev. Stud.* 36, 163–178. doi: 10.1080/02255189.2015.1046373

Köberle, . C., Holtedahl, P., and Singh, M. G. (2021). *Future of Food Part 2-Nature-based Solutions and the Quest for Low-Carbon and Climate-Resilient griculture*. Centre for Climate Finance and Investment, Imperial College Business School. vailable online at: https://www.imperial.ac.uk/business-school/faculty-research/research-centres/centre-climate-finance-investment/research/future-food-part-2-nature-based-solutions-and-the-quest-low-carbon-and-climate-resilient/ (accessed December 2, 2022).

Lawlor, K., and Weinthal, E. (2010). Institutions and policies to protect rural livelihoods in REDD + regimes. *Glob. Environ. Polit.* 10, 1–11. doi: 10.1162/GLEP_a_00028

Lewis, S. L., Wheeler, C. E., and Mitchard, E. T. . (2019). restoring natural forests is the best way to remove atmospheric carbon. *Nature* 568, 25–28. doi: 10.1038/d41586-019-01026-8

Martin, M. P., Woodbury, D. J., Doroski, D. ., Nagele, E., Storace, M., Cook-Patton, S., et al. (2021). People plant trees for utility more often than for biodiversity or carbon. *Biol. Conserv.* 261, 109224. doi: 10.1016/j.biocon.2021.109224

Matthews, H. D., Zickfeld, K., Dickau, M., MacIsaac, . J., Mathesius, S., Nzotungicimpaye, C. M., et al. (2022). Temporary nature-based carbon removal can lower peak warming in a well-below 2 °C scenario. *Commun. Earth Environ.* 3, 1–8. doi: 10.1038/s43247-022-00391-z

McLain, R., Lawry, S., and Guariguata, M. R. (2021). Toward a tenure-responsive approach to forest landscape restoration: a proposed tenure diagnostic for assessing restoration opportunities. *Land Use Policy* 104, 103748. doi: 10.1016/j.landusepol.2018.11.053

Milne, S., Mahanty, S., To, P., Dressler, W., Kanowski, P., Thavat, M., et al. (2019). Learning from 'actually existing' REDD+: a synthesis of ethnographic findings. *Conserv. Soc.* 17, 84–95. doi: 10.4103/cs.cs_18_13

Noss, R. F. (1990). Indicators for monitoring biodiversity: a hierarchical approach. *Conserv. Biol.* 4, 355–364. doi: 10.1111/j.1523-1739.1990.tb00309.x

Porter-Bolland, L., Ellis, E. ., Guariguata, M. R., Ruiz-Mallén, I., Negrete-Yankelevich, S., Reyes-García, V., et al. (2012). Community managed forests and forest protected areas: n assessment of their conservation effectiveness across the tropics. *For. Ecol. Manage.* 268, 6–17. doi: 10.1016/j.foreco.2011.05.034

Richards, C. (2016). The new corporate enclosures: plantation forestry, carbon markets and the limits of financialised solutions to the climate crisis. *Land Use Policy* 56, 209–216. doi: 10.1016/j.landusepol.2016.05.013

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, I. I. I., Lambin, F. S., et al. (2009). Planet boundaries: exploring the safe operating space for humanity. *Ecol. Soc.* 14, 32.

Sacco, D., Hardwick, ., Blakesley, K. ., Brancalion, D., Breman, P. H., Ten, E., et al. (2021). Golden rules for reforestation to optimize carbon sequestration, biodiversity recovery and livelihood benefits. *Glob. Chang. Biol.* 27, 1328–1348. doi: 10.1111/gcb.15498

Seddon, N. (2022). Harnessing the potential of nature-based solutions for mitigating and adapting. *Climate Change*. 1416, 1410–1416. doi: 10.1126/science.abn9668

Seddon, N., Chausson, ., Berry, P., Girardin, C. ., and Smith, . (2020). Understanding the value and limits of nature-based solutions to climate change and other global challenges. Philos. *Trans. R. Soc. B Biol. Sci.* 375, 120. doi: 10.1098/rstb.2019.0120

Seddon, N., Sengupta, S., García-Espinosa, M., Hauler, I., Herr, D., Rizvi, . R., et al. (2019). *Nature-Based Solutions in Nationally Determined Contributions: Synthesis and Recommendations for Enhancing Climate mbition and ction by 2020*. Gland; Oxford: IUCN and University of Oxford.

Seddon, N., Smith, ., Smith, P., Key, I., Chausson, ., Girardin, C., et al. (2021). Getting the message right on nature-based solutions to climate change. *Glob. Chang. Biol.* 27, 1518–1546. doi: 10.1111/gcb.15513

Tastle, W. J., and Wierman, M. J. (2007). Consensus and dissention: a measure of ordinal dispersion. *Int J ppro. Reasoning* 45, 531–545. doi: 10.1016/j.ijar.2006.06.024

Turnhout, E. (2020). . Biodiversity and species extinction: categorisation, calculation, and communication. *Griffith Law Rev.* 29, 669–685. doi: 10.1080/10383441.2020.1925204

United Nations Development Programme. (2019). *Pathway for Increasing Nature-based Solutions in NDCs: Seven-Step pproach for Enhancing Nationally Determined Contributions through Nature-based Solutions*. New York, NY: United Nations Development Programme.

Veldman, J. W. (2019). Comment on "The global tree restoration potential". *Science*. 366, 1–5. doi: 10.1126/science.aay7976

Wardell, D. . (2021). *Facilitating the Shift From Tree Planting to Promoting Community-Based Forest Enterprises in the Philippines. Policy Brief No. 57*. Los Baños: World groforestry, Department of Environment and Natural Resources, sian Development Bank, Global Environment Facility.

Waring, B., Neumann, M., Prentice, I. C., dams, M., Smith, P., Siegert, M., et al. (2020). Forests and decarbonization – roles of natural and planted forests. *Front. For. Glob. Chang.* 3, 1–6. doi: 10.3389/ffgc.2020.00058

West, T. . P., Börner, J., and Sills, E. O. (2020). overstated carbon emission reductions from voluntary REDD+ projects in the Brazilian mazon. *PN S* 117, 24188–24194. doi: 10.1073/pnas.2004334117

White, ., and Martin, . (2002). *Who Owns the World's Forests*. Washington, DC: Forest Trends.

Zelikova, J., Chay, F., and Freeman, J. D. (2021). *Buyer's Guide to Soil Carbon Offsets*. vailable online at: https://carbonplan.org/research/soil-protocols-explainer