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Authors:

Shannon Osaka

ORCID iD: 0000-0003-1937-2368; Department of Geography, University of Manchester, Manchester, UK; sosaka@alumni.princeton.edu

Rob Bellamy*

ORCID iD: 0000-0001-9592-705X; Department of Geography, University of Manchester, Manchester, UK; rob.bellamy@manchester.ac.uk

Noel Castree

ORCID iD: 0000-0001-9592-705X; School of Communication, University of Technology Sydney, Sydney, Australia; noel.castree@manchester.ac.uk

Abstract

In recent years, there has been a growth in scholarship on “nature-based solutions” and “natural climate solutions” to climate change. A variety of actors have argued that these natural solutions – variously involving the protection, conservation, restoration, management, enhancement, or imitation of natural ecosystems – can play a crucial role in both mitigating and adapting to climate change. What is more, by virtue of their label, natural solutions promise to be particularly attractive to the public and policymakers and have received significant media and scholarly attention. But what is natural is also social: people, acting in various social groups, can selectively emphasise or deemphasise certain characteristics of climate solutions to make them seem more or less natural. The framing of particular solutions as ‘natural’ or ‘unnatural’ has far-reaching implications for climate policy but has thus far been overlooked. Here we undertake a critical review of the ways in which natural solutions to climate change have been framed and examine the normative and practical implications of this framing. We review what counts (and what does not count) as a natural solution, and find that those labelled natural are routinely framed under technical and social appraisal criteria as being more beneficial, cost effective, mature, and democratic than ostensibly artificial counterparts. And yet, we show that under greater scrutiny, the natural framing obscures the reality that natural solutions can be just as risky, expensive, immature, and technocratic. We conclude by reflecting on the dangers of narrowing the range of solutions considered natural and indeed, of selecting solutions through recourse to ‘nature’ at all. Rather, climate solutions must be evaluated in terms of their specific qualities, against a far broader range of framings.

1. INTRODUCTION

Over the past decade a variety of actors have suggested a new set of solutions for ameliorating the problem of global anthropogenic climate change. These policy options, called “nature-based solutions” or “natural climate solutions,” involve the protection, conservation, restoration, management, enhancement or imitation of natural ecosystems, and might include forest conservation and management, wetland restoration, biochar burial, and peatland conservation and restoration. These solutions have garnered increasing media, policy, and scholarly attention, with supporters ranging from teen activist Greta Thunberg to the European Commission (European Commission, 2015; Carrington, 2019). According to one widely cited paper, such solutions could provide 30% of the cost-effective mitigation of climate change that would help individual nations, and the planet as a whole, keep global warming to below 2° C above pre-industrial levels (Griscom et al., 2017). Meanwhile, an analysis of signatories to the Paris Agreement suggests that two-thirds of countries already include natural solutions in some form in their nationally determined contributions (Seddon, Sengupta, et al., 2020).

Although the current discourse of natural solutions for climate change is relatively new (Griscom et al., 2017; Fargione et al., 2018; Seddon et al., 2021), there is a much longer history in policymaking around “natural” or “ecosystem-based” solutions for mitigation and adaptation to climate change. Indeed, the idea of natural solutions to climate change can be traced back to much earlier scholarship on using natural ecosystems for various utilitarian human purposes. Although traditional belief systems have long referenced the importance of ecosystems for human welfare, the scientific conception of ecosystem services arose in the 1980s (Ehrlich & Mooney, 1983) and rose to prominence in the 1990s and 2000s (Daily, 1997; Lele et al., 2013). The United Nations-commissioned Millennium Ecosystem Assessment in the early 2000s further legitimized the idea of ecosystem services by performing a comprehensive appraisal of the world's ecosystems and their ability to deliver services such as clean water, food, and disaster management (Millennium Ecosystem Assessment, 2005).

The late 2000s witnessed a new addition to the lexicon of environmental management – "nature-based solutions" for climate change and other environmental problems (Cohen-Shacham et al., 2016; Nesshöver et al., 2017) Nature-based solutions (NbS) suggested a conceptual shift towards ecosystems not only providing services, but also serving as a "significant contribution to addressing major societal challenges" (Eggermont et al., 2015; Cohen-Shacham et al., 2016, p. 3). Originating at the interface of science, policy, and practice, NbS were championed by international environmental organizations such as the International Union for the Conservation of Nature, the World Wildlife Fund, the World Bank, and others as an alternative to "conventional engineering" or other interventions to solve human problems (MacKinnon et al., 2008; Dudley, 2010; Cohen-Shacham et al., 2016). According to one working definition of NbS, "Nature-based Solutions (NbS) use ecosystems and the services they provide to address societal challenges such as climate change, food security, or natural disasters" (Cohen-Shacham et al., 2016, p. 2).

NbS were joined in the late 2010s by the new framework of "natural climate solutions", originally highlighted in the academic literature by Griscom et al. (2017). Natural climate solutions or NCS, have many similarities with NbS but are focused more narrowly on climate change mitigation (see Section 2). Researchers focusing on NCS have foregrounded their importance in reducing or avoiding emissions in order to meet the goals of the 2015 Paris agreement (Fargione et al., 2018; Griscom et al., 2020).

Although there are some differences between NbS and NCS (see Section 2), both solution frameworks benefit from the "natural" label. Actions or policies that are considered "natural" often correspond with higher public approval, while those that can be seen as "tampering with" or "messing with" nature are viewed as less desirable or more risky (Sjöberg, 2000; Hansen, 2006; Corner et al., 2013). Meanwhile, the problem of climate change has been more broadly depicted as the "end of nature" (McKibben, 1989), or as an example of humans overstepping the bounds of the natural world via artificial and industrial energy technologies (Rockström et al., 2009). Against this backdrop, NCS and NbS seem to be crucial policy options which can garner widespread public support while also helping to return the planet to a more "natural" climatic state; they can also be seen as ways to engender increased public and policy support for conservation goals, even as funding and attention revolves around a focus on mitigating and adapting to climate change.

But what counts as a natural solution to climate change? And how should natural solutions be delineated from solutions which are inadvertently, or tacitly, specified as "unnatural"? It has been widely argued in the social sciences (Castree, 2005; Hinchliffe, 2007), and in relation to NCS in particular (Bellamy & Osaka, 2020) that there is no singular, external, non-human nature – rather, the concept of nature is socially constructed, and imbued with particular socio-political meanings in specific contexts. Therefore, defining and presenting a particular course of action or policy as "natural" can itself be a political act, with consequences for how such policies are interpreted and leveraged in the public sphere. Some scholars have also suggested that there is no strict dividing line between "natural" and "unnatural"; instead, they argue that the world is made up of co-produced nature-culture hybrids, in which the natural and artificial components cannot be easily disentangled (Latour, 2004; Hinchliffe, 2007).

We suggest, therefore, that there is a need for a critical review into the "nature" of natural solutions to climate change. Here we provide a brief history and present various definitions of "natural climate solutions" and "nature-based solutions" for climate change, followed by a systematic examination of recent literature. By analysing how these solutions are framed via a range of technical and social appraisal criteria, we examine how they have been differentiated from other policy options that are inadvertently, tacitly, or deliberately framed as unnatural. Finally, we examine the implications of these framings for climate politics and discourse, exploring the broader theoretical and practical implications of this use of "nature".[1]

[1] In this paper, we are interested in the assignation of meaning, taking meaning to be 'material' in the way natural solutions themselves are when actioned and implemented. We are 'constructivists' in the discursive sense, as well the in the sense of 'building' technologies or intervening in ecosystems. Our position accepts that 'reality' is, in part, apprehended through

2. DEFINING "NATURAL" SOLUTIONS

Natural solutions to climate change are currently represented by two distinct and yet interconnected terms: nature-based solutions (NbS)[2] and natural climate solutions (NCS). These concepts arose at different times and in slightly different institutional contexts; thus, although they are closely related, there are significant differences in how they are framed, both in academic and grey literature and in public discourse.

As briefly detailed in the introduction, the concept of NbS predates NCS by almost a decade. NbS emerged in the grey literature in the mid- to late-2000s, advocated for by organizations like the International Union for the Conservation of Nature (IUCN) and the World Bank (MacKinnon et al., 2008; IUCN (International Union for the Conservation of Nature), 2009; MacKinnon & Hickey, 2009). The earliest mentions of NbS focused on their applicability for mitigation and adaptation to climate change (MacKinnon et al., 2008; IUCN, 2009). For example, in a World Bank report from 2008, NbS were not substantively defined, but included interventions such as afforestation, grassland restoration, and enhancing landscape connectivity to both mitigate and adapt to climate change (MacKinnon et al., 2008).

Over the past decade, however, the NbS concept has broadened to include a range of social and environmental problems. The European "Horizon 2020" research and innovation program, which incorporated a focus on NbS, suggested that these solutions could lead to economic development and sustainable urbanization, as well as ameliorating climate change and restoring degraded ecosystems (European Commission, 2015). A recent report from IUCN laying out standards for NbS suggests that they could be used to provide food and water security and disaster risk reduction as well as climate change mitigation and adaptation (IUCN, 2020). Current definitions of NbS include this wide focus on a range of social and environmental issues (Table 1), and the European Commission has also suggested that NbS could be useful to support "green growth" and provide business opportunities (European Commission, 2015).

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categories that, in turn, influence attempts to shape it. Andreas Malm (2018) has recently called for a return to realism in critical studies of nature in social science and the humanities. While accepting his call, we disavow any 'pure' realism that avoids the social skein of language.

[2] Occasionally other terminology is used for the same purpose: In Dudley et al. (2010), the authors refer to "natural solutions" instead of NbS, but in all other respects the solutions put forward in that report appear analogous to NbS. See also Section 3.

Table 1. Definitions of nature-based solutions.

Source	Definition
(Balian et al., 2014, p. 5)	"…[T]he use of nature in tackling challenges such as climate change, food security, water resources, or disaster risk management, encompassing a wider definition of how to preserve and use biodiversity in a sustainable manner."
(Cohen-Shacham et al., 2016, p. xii)	"…[A]ctions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges (e.g. climate change, food and water security or natural disasters) effectively and adaptively, simultaneously providing human well-being and biodiversity benefits."
(European Commission, 2015, p. 24)	"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."
(Seddon, Chausson, et al., 2020, p. 2)	"NbS involve working with and enhancing nature to help address societal challenges."

Numerous researchers have pointed out that NbS are not necessarily well-defined, and may have significant overlaps with other terms, including ecological engineering, green or blue infrastructure, the ecosystem approach, and ecosystem-based adaptation or mitigation (Eggermont et al., 2015; Kabisch et al., 2016; Faivre et al., 2017; Nesshöver et al., 2017; Pauleit et al., 2017). Therefore, some suggest viewing NbS as an "umbrella concept", which "covers a whole range of ecosystem-related approaches all of which address societal challenges" (Cohen-Shacham et al., 2016, p. 10; Pauleit et al., 2017). Perhaps because of these (overly) broad definitions, examples of NbS for climate change are various and differ greatly in scale. The European Commission (2015) has suggested 310 potential actions that could fit the criteria for NbS, ranging from reforestation, soil conservation, wetland management, and green roofs; others have suggested actions including preventing the loss of ecosystems that serve as climate sinks or restoring coastal ecosystems to protect from extreme weather (Eggermont et al., 2015; Faivre et al., 2017; Seddon, Chausson, et al., 2020)

Table 2. Nature-based solutions (NbS) vs. natural climate solutions (NCS).

	Nature-based solutions (NbS)	**Natural climate solutions (NCS)**
Social and environmental challenges addressed	Food and water security; climate change adaptation and mitigation; disaster risk management; flood control; economic growth	Climate change mitigation (with associated co-benefits)

If NbS are sprawling and wide-ranging in their applicability, however, natural climate solutions (NCS) are more narrowly focused and tailored to a very specific problem: the need for climate change mitigation (see Table 2). Spearheaded by Griscom et al. (2017), NCS are intended to "increase carbon storage and avoid greenhouse gas emissions" via enhanced carbon sinks and other means (Fargione et al., 2018, p. 1). NCS have not been cited directly as adaptation tools, although climate resilience has been listed as one of the expected co-benefits of their development, along with flood control, increased biodiversity, and soil health (Griscom et al., 2017; Graves et al., 2020; Griscom et al., 2020). Examples of NCS are thus concentrated on those actions that are both considered "natural" and that lead to the greatest mitigation effects – Griscom et al. (2017) and Fargione et al. (2018) have compiled fairly comprehensive lists of approximately 20 examples of NCS, including reforestation, coastal restoration, biochar, and cropland nutrient management (see Table 3).

Table 3. A non-exhaustive list of examples of nature-based solutions (NbS) and natural climate solutions (NCS).

Nature-based solutions (NbS)	**Natural climate solutions (NCS)**

Afforestation; agroforestry; coastal management; restoration of floodplains; reforestation; forest protection; mangrove restoration; grassland management; soil conservation; green roofs; green walls; urban open spaces and reforestation; wind breaks, rainwater capture; wetland restoration; community gardens (Albert et al., 2017; Nesshöver et al., 2017)	Reforestation; natural forest management; improved plantations biochar; cropland nutrient management; grassland restoration; tidal wetland restoration; peatland restoration; avoided woodfuel (Fargione et al., 2018; Griscom et al., 2017)

For both NbS and NCS, the "nature" of natural solutions remains somewhat ambiguous and in dispute. NbS and NCS generally involve some form of restoration, conservation, management, enhancement, or imitation of a natural ecosystem. But questions remain about the extent of management or enhancement that is acceptable for a solution to be considered "natural," and the naturalness of that ecosystem in the first place (Potschin et al., 2016; Albert et al., 2017). Some authors have suggested categorizing NbS along a spectrum from "less engineered" to "more engineered" solutions (Cohen-Shacham et al., 2016; Eggermont et al., 2015). Under this system, Type 1 NbS are solutions that consist of no or minimal intervention in existing ecosystems; Type 2 involve enhancing or diversifying existing ecosystems or agricultural lands, and Type 3 involve designing or managing entirely new ecosystems such as green roofs and walls (Eggermont et al., 2015). But this typology is still quite broad, and leaves space for many types of hybrid solutions – an NbS may begin as a Type 3 solution but over time come to be seen as a Type 1.

Meanwhile, some solutions might qualify as natural under one framework, but not another (Nesshöver et al., 2017). Cohen-Shacham et al. (2016) wonder if, for example, an oil-palm plantation used for biofuel production, or manufactured technologies (such as wind turbines or solar panels) that make use of natural phenomena, should count as NbS. Others have asked whether genetically modified organisms should be considered as well, or automatically excluded (Nesshöver et al., 2017). Eggermont et al. (2015) argue that some solutions which seem "nature-based" should be excluded based on a lack of alignment with natural ecosystems: for example, green roofs which are made only of one or two species from different geographical distributions (see also Seddon, Chausson, et al., 2020). Indeed, the boundary between natural solutions and other types of solutions is not as sharp as it might originally seem, owing perhaps to the ambiguity and conceptual complexity of the idea of "nature" itself (Castree, 2005, 2014).

More often than not, natural solutions seem to be defined in opposition to other solutions – those that are either deliberately, tacitly or inadvertently labeled as "unnatural". NCS and NbS are often described in contrast or as complements to more technological or "engineered" solutions, which are sometimes framed as being less desirable (see Section 3). For example, Eggermont et al. (2015, p. 243) contrast "technological strategies" – which are designed to be as simple and replicable as possible – with NbS, which involve sustainably managing "(socio-)ecological systems." In the adaptation case, natural solutions such as mangrove or wetland restoration are contrasted with "conventional engineering" approaches, such as the building of sea walls or dikes (Depietri & McPhearson, 2017). In the mitigation case, NCS have been contrasted with emerging technologies for carbon removal, such as bioenergy with carbon capture and storage (BECCS) or direct air capture (Griscom et al., 2017; Fargione et al., 2018). But in some cases, again, the boundaries are not clear-cut; for instance, biochar burial has been cited as a NCS (Griscom et al., 2017; Fargione et al., 2018), while BECCS has not, even though both involve enhancing an existing natural process (biomass growth) with items manufactured from nature (for biochar, pyrolysis plants, and for BECCS, power stations with carbon capture and storage).

In general, natural solutions are considered to be less engineered and less technological than other climate solutions – but the way in which those determinations are made may be highly flexible and variable. Beyond these definitional questions, however, it is also salient to examine the way that natural solutions are framed in a subset of the available literature, and the way that they are characterized under a range of social and technical criteria. In the following section, we systematically explore these framings, and through them how natural solutions can be presented (or contested) as an ostensibly preferable option for addressing the dangers of climate change.

3. FRAMING "NATURAL SOLUTIONS"

3.1 Review method

We utilized a systematic strategy for screening and identifying relevant articles on "nature-based solutions" and "natural climate solutions" in primarily academic, but also some grey, literature. Using the Web of Knowledge electronic database, we conducted a search for English-language articles including “nature-based solutions” AND “climate change” OR “natural climate solutions” in the title. The resulting articles were screened for relevance – articles and book chapters that focused primarily on NbS or NCS in relation to climate change and included a substantive definition of the solutions under discussion were included. The Web of Knowledge search returned a total of 35 articles, of which 24 met the inclusion criteria; these articles were then supplemented with a Google Scholar search and a snowballing technique to identify frequently cited articles within academic and grey literature. This approach added 9 articles and reports, bringing the total number of works under review to 33.

For each article, we reported and tabulated its methodological approach, whether it focused primarily on NbS or NCS and climate adaptation or mitigation, its primary conclusions, and how NbS and NCS were framed within the piece. By the term ‘frames’, we mean the underlying assumptions that guide how the natural solutions in question were defined, depicted, or characterized in contrast to other potential solutions for adaptation and mitigation (Miller, 2000). In particular, we used established procedures for inductive, semantic, and realist thematic analysis to examine how NbS and NCS were described (their definitions), and what qualities they were depicted as having in contrast to more traditional or “engineered” solutions (Braun & Clarke, 2006). Following Stirling (2008), our interest in such qualities – as the outputs of applied technical and social appraisal criteria – arises from their power to ‘open up’ or ‘close down’ governance commitments in science and technology policy generally, and in climate change policy in particular (Bellamy et al., 2012). These frames were elicited primarily from the abstracts, introductions, and conclusions of the articles in question and reported in a comprehensive table (see Table 4). Finally, each paper was examined for the presence of reflexivity, or the transparent acknowledgement of ambiguities around the usage of “nature” and uncertainties around the ways in which their performances under different criteria were presented.

Table 4. Nature-based solutions (NbS) and natural climate solutions (NCS) literature included in the review.[3]

	Source	Approach and methods	Notes on framing and conclusions

[3] Eleven papers in the study sample focused exclusively on NCS and climate change mitigation; 22 focused on NbS, of which 9 included adaptation and mitigation, and 13 more narrowly focused on NbS as adaptation-only.

1	(Qin et al., 2021)	Simulation and analysis of the speed at which NCS can be deployed for climate change mitigation	• Focuses on mitigation, NCS • Concludes that previous estimates of NCS mitigation potential may be overestimated due to temporal delays; categorizes and suggests ways to ameliorate these delays • Caveats framing of NCS as effective and available mitigation options due to potential delays
2	(Fleischman et al., 2020)	Perspective paper on the pitfalls of tree planting as an NCS	• Focuses on mitigation, NCS • Concludes that tree plantations should not qualify as a NCS, owing to concerns over effectiveness, governance, and indigenous land rights • Argues that NCS are only effective if they respond to rural and indigenous needs; fast-growing trees should not be considered an NCS
3	(Chausson et al., 2020)	Systematic mapping evaluation of evidence around the effectiveness of NbS for climate change adaptation	• Focuses on adaptation, NbS • Concludes that NbS interventions in natural or 'semi-natural' ecosystems were effective; created ecosystems came with attendant trade-offs • Frames NbS through their co-benefits and ability to address multiple sustainable development goals; points to significant gaps in evidence base in comparing NbS and traditional solutions
4	(Townsend et al., 2020)	Editorial on the importance of indigenous peoples in implementing NbS	• Focuses on mitigation (framed here as NbS) • Concludes that effective NbS for mitigation in Canada will require the cooperation and participation of indigenous peoples • Frames NbS through effectiveness in CO_2 mitigation
5	(Graves et al., 2020)	Simulation and analysis of the potential greenhouse gas reductions through NCS in Oregon, USA	• Focuses on mitigation, NCS • Quantifies potential emissions reductions of NCS in Oregon by 2030 and 2050 • Frames NCS as providing valuable co-benefits in addition to climate change mitigation
6	(Jin et al., 2020)	Simulation and analysis of the role of forests in meeting China's emissions targets	• Focuses on adaptation, NbS • Estimates forests emissions reduction potential of China and determines current target sinks have not been met • Frames NbS briefly as providing co-benefits for flood control, food, medicine, etc.
7	(DeLosRíos-White et al., 2020)	Design of framework for implementation and development of NbS in urban environments	• Focuses on adaptation, NbS • Develops a framework for the co-creation of NbS through stakeholder engagement • Frames NbS as cost-effective and participatory approaches for adapting urban and peri-urban ecosystems to climate change
8	(Crusius, 2020)	Simulation and analysis of the role of NCS in keeping global warming below 1.5 degrees C	• Focuses on mitigation, NCS • Concludes that NCS can assist in mitigation efforts but that NCS interventions may not be permanent due to future climate or land-use changes • Frames NCS as rapidly deployable and effective solutions for mitigation, with caveats
9	(Bossio et al., 2020)	Analysis of the role in soil carbon	• Focuses on mitigation, NCS • Concludes that soil carbon represents 25% of the potential of global NCS

		sequestration in global NCS	• Frames soil carbon sequestration as including positive co-benefits and requiring little additional land use
10	(Griscom et al., 2020)	Simulation and analysis of potential greenhouse gas reductions through NCS in all tropical countries	• Focuses on mitigation, NCS • Concludes that cost-effective tropical NCS offer significant potential emissions reductions • Frames NCS as essential actions to reach Paris Agreement goals which include co-benefits for air, biodiversity, water, and soil
11	(Macias-Fauria et al., 2020)	Review and scoping exercise for megafaunal ecological engineering as a potential NCS	• Focuses on mitigation, NCS • Concludes that a megafaunal NCS in the Arctic can bring income on carbon market but may be difficult to scale • Frames NCS as a way to simultaneously address both mitigation and biodiversity declines; suggests an approach for a “rewilding” version of NCS
12	(Seddon, Chausson, et al., 2020)	Review on the potential benefits and drawbacks of NbS for climate change	• Focuses on adaptation and mitigation, NbS • Concludes that the potential of NbS to provide benefits and co-benefits has not been rigorously assessed; outlines barriers to NbS implementation • Frames NbS as having advantages over traditional negative emissions or adaptation solutions, but caveats these advantages depending on support of biodiversity and implementation by local communities
13	(Wamsler, Wickenberg, et al., 2020)	Applied participatory analysis of municipalities attempting to implement NbS	• Focuses on adaptation, NbS • Concludes that NbS for climate adaptation governance requires more financial and human resources • Frames NbS through their provision of co-benefits; as challenging to implement due to the difficulty of navigating transdisciplinary structures
14	(Wamsler, Alkan-Olsson, et al., 2020)	Participatory analysis of Swedish municipalities attempting to implement NbS	• Focuses on adaptation, NbS • Concludes that citizen engagement can hamper sustainable NbS outcomes under current conditions • Frames NbS through their use of ecosystem services and provision of co-benefits; questions common framing of NBS as supporting transdisciplinary governance
15	(Kalt et al., 2019)	Simulation and analysis of the carbon savings of bioenergy vs NCS of natural succession	• Focuses on mitigation, NCS • Concludes that natural succession is a competitive climate solution compared to bioenergy, but presents risks • Frames this NCS as low-cost and effective, with co-benefits, but potentially not reliable in the long-term
16	(Frantzeskaki et al., 2019)	Co-production of synthesis statements on the role of NbS in urban contexts via a series of workshops	• Focuses on adaptation, NbS • Suggests ways of advancing planning and knowledge agenda for NbS • Frames NbS as coming with associated co-benefits (and potential unintended consequences), argues they are complementary to technology-, cultural-, and behavior-based solutions
17	(Anderson et al., 2019)	Perspective paper on the role of NCS in mitigation planning	• Focuses on mitigation, NCS • Argues that NCS should not detract from a focus on decreasing emissions from energy and industry • Frames NCS as coming with significant co-benefits but also significant barriers
18	(Griscom et al., 2017)	Quantification and analysis of global	• Focuses on mitigation, NCS • Concludes that NCS can provide 37% of cost-effective mitigation through 2030

		mitigation potential from NCS	• Frames NCS as providing multiple co-benefits and as more cost-effective than carbon removal options such as bioenergy with carbon capture and storage
19	(Fargione et al., 2018)	Quantification and analysis of U.S. mitigation potential from NCS	• Focuses on mitigation, NCS • Concludes NCS can provide maximum potential carbon storage of 21% of current U.S. emissions • Frames NCS as the most mature options for negative emissions as well as producing multiple co-benefits
20	(Emilsson & Sang, 2017)	Review on the role of NbS in ameliorating high temperatures in urban environments	• Focuses on adaptation, NbS • Concludes that NbS can increase adaptive capacity and reduce climate impacts • Frames NbS as including co-benefits and as involving participatory creation and governance
21	(Pauleit et al., 2017)	Literature review analyzing the relationship of NbS, ecosystem-based adaptation, urban green infrastructure, and ecosystem services	• Focuses on adapatation and mitigation, NbS • Concludes NbS is a 'powerful metaphor' which depends on related terms for uptake and definition • Frames NbS as a broad suite of solutions that address several policy objectives simultaneously
22	(Depietri & McPhearson, 2017)	Analysis of case studies and lit review on the role of 'grey,' 'green,' and 'blue' infrastructure in urban environments	• Focuses on adaptation, NbS • Concludes that a 'hybrid' approach which combines NbS with traditional 'grey' infrastructural strategies is most effective • Frames NbS as more cost-effective, and with more co-benefits, than 'grey' infrastructure, but with only medium resilience
23	(Enzi et al., 2017)	Analysis of the microclimate and economic impact of NbS for buildings	• Focuses on adaptation, NbS • Describes best practices for green roofs and green walls in building construction • Frames NbS for buildings as coming with co-benefits and as a business opportunity
24	(Kabisch et al., 2016)	Expert transdisciplinary workshop with representatives from research, cities, policy, and society	• Focuses on adaptation and mitigation, NbS • Maps knowledge gaps, potential barriers, and opportunities around NbS; proposes NbS indicators • Frames NbS as coming with multiple co-benefits as well as being potentially more efficient and cost-effective than traditional approaches
25	(Cohen-Shacham et al., 2016)	Report from the IUCN introducing definitional principles for NbS and multiple case studies	• Focuses on adaptation and mitigation, NbS • Defines NbS and develops preliminary parameters to assess them along governance and ecological lines • Frames NbS as addressing societal challenges while providing associated co-benefits to humans and biodiversity
26	(Calliari et al., 2019)	Proposal of assessment framework for	• Focuses on adaptation, NbS • Presents 'dynamic' assessment framework for NbS to be applied *ex ante* to choose between traditional and NbS

		NbS under a changing climate	options • Frames NbS as cost-effective, providing co-benefits, and involving multi-stakeholder engagement
27	(Seddon et al., 2021)	Review paper developing guiding principles for the implementation and definition of NbS	• Focuses on mitigation and adaptation, NbS • Argues that NbS should have benefits for biodiversity and indigenous/local communities, and that they are not a substitute for winding down fossil fuel use • Suggests that NbS should be more narrowly framed along 4 key guidelines, and that poorly designed NbS can have deleterious impacts
28	(Potschin et al., 2016)	Synthesis paper discussing definitions and frameworks for NbS	• Focuses broadly on mitigation and adaptation, NbS • Concludes that there are many open questions about how to define and understand NbS • Frames NbS as similar to existing terminologies but focused more specifically on 'solutions'
29	(Seddon, Sengupta, et al., 2020)	Analysis of the inclusion of NbS in nationally determined contributions to the Paris Agreement	• Focuses on adaptation, NbS • Concludes that intentions to deploy NbS vary widely and rarely translate into evidence-based targets • Frames NbS as a complement to 'grey' or 'soft' interventions for adaptation
30	(Seddon et al., 2019)	Comment paper critiquing narrow focus of NbS on tree plantations	• Focuses on adaptation and mitigation, NbS • Argues that biodiversity should be a crucial component of evaluating and deploying NbS • Frames NbS as cost-effective and coming with co-benefits, but only if they incorporate biodiversity
31	(Frantzeskaki, 2019)	Analysis of NbS case studies in 11 European cities	• Focuses on adaptation, NbS • Concludes that NbS require local government trust, collaborative governance, and aesthetic appeal • Frames NbS as 'superior' to grey infrastructure, providing co-benefits, and requiring participatory governance
32	(Nesshöver et al., 2017)	Review paper analyzing NbS and similar concepts	• Focuses on mitigation and adaptation, NbS • Concludes that NbS need to be placed into context with existing concepts, and developed via stakeholder engagement • Caveats framing of NbS as 'cheap and easy' and advises a moderation of expectations
33	(Eggermont et al., 2015)	Review paper presenting a typology, risks, and opportunities of NbS	• Focuses on mitigation and adaptation, NbS • Argues that NbS can integrate science, policy and create biodiversity benefits • Frames NbS as providing ecosystem services and co-benefits

3.2 Findings

3.2.1 Co-benefits

The most dominant and extensive framing in the literature reviewed was that of co-benefits. Many of the articles under review framed NCS or NbS as coming with significant additional advantages for biodiversity or as providing ecosystem services that can support human health and well-being. The concept of co-benefits, which has been used widely in literature on environmental management and climate policy, can be defined as the positive effects that a policy or measure has on human or environmental welfare in addition to its original purpose or goal (Mayrhofer & Gupta, 2016). In papers on NCS, authors suggested that these solutions – such as avoided deforestation or the restoration of coastal habitats – could also enhance biodiversity, improve habitats, decrease air and water pollution, protect against extreme events, and increase soil fertility, thus providing more reason to accelerate their implementation (Griscom et al., 2017; Anderson et al., 2019; Bossio et al., 2020; Graves et al., 2020; Macias-Fauria et al., 2020). Put another way, one of the co-benefits of natural solutions for climate mitigation is that those measures may also be useful for climate adaptation, and occasionally vice versa. Anderson et al. (2019, p. 934), for example, suggest that "the co-benefits of NCS may be more valuable than the carbon mitigation benefit" – which could render them a kind of no-regrets policy solution even if their mitigation potential is limited (Graves et al., 2020).

The "co-benefits" framing was also prevalent in the NbS literature under review (e.g., Cohen-Shacham et al., 2016). Natural solutions for climate adaptation were cited as having co-benefits for biodiversity, ecosystem services, and for the well-being of local communities (Chausson et al., 2020; Kabisch et al., 2016). Cohen-Shacham et al. (2016) give the example of wetland restoration in the Miyagi prefecture of Japan, where conservation of wetlands increased biodiversity and also raised the incomes of local farmers. Others argue that green spaces in city environments – which alleviate urban heat island effects and thus ameliorate climate extremes – can also improve psychological well-being and reduce air pollution (Eggermont et al., 2015; Kabisch et al., 2016).

Implicit, and sometimes explicit, in the co-benefits framing was the belief that traditional – or what we might call "unnatural" – solutions have few benefits beyond their original purpose and could even cause negative externalities. In the case of NCS, for example, Griscom et al. (2017, p. 11647) contrast natural solutions with other solutions such as BECCS, arguing that large-scale BECCS "is likely to have significant impacts on water use, biodiversity, and other ecosystem services." Some of the NbS papers under review take a similar position – Depietri and McPhearson (2017), for example, argue that while "green infrastructures" provide a wide swath of ecosystem services and co-benefits, "grey infrastructures" have limited or "low" co-benefits. The literature reviewed on NbS, however, also included caveats and occasional contestations of the co-benefits framing. Seddon et al. (2021), for example, argue that some solutions which may seem to be NbS (tree plantations for afforestation, for example), do not include significant biodiversity benefits and therefore should not be considered true nature-based solutions. Seddon et al. (2019, p. 85) point out that “high-level pledges for ‘nature’ tend to translate into targets for afforestation, often monocultures with non-native species, which can over the long term … negatively impact biodiversity and sustainable development in general”, thus eroding some potential NbS co-benefits. Others highlight the fact that NbS may come with potential drawbacks, including health risks (via allergies or infectious diseases) and the hampering of local incomes through occupying needed agricultural land.

3.2.2 Cost-effectiveness

The second most prevalent framing in the literature reviewed on NbS and NCS was that of “cost-effectiveness”, particularly in comparison to traditional or engineered solutions. In the NCS literature reviewed, cost-effectiveness most often appeared in a highly quantified context (in keeping with the trend in NCS literature toward modelling analyses). For example, natural solutions in NCS literature were characterized as contributing significantly to the “cost-effective mitigation” (defined by Griscom et al. (2017) as less than $100 per metric ton of CO2 equivalent) required to limit global warming to 2 degrees Celsius (Griscom et al., 2017; Crusius, 2020; Griscom et al., 2020). On the NbS side, meanwhile, cost-effectiveness was primarily referred to in definitional terms, as a critical component of what makes a nature-based solution a nature-based solution (Kabisch et al., 2016; Pauleit et al., 2017; DeLosRíos-White et al., 2020). Authors drew from either the IUCN or European Commission definitions, articulating NbS as “cost-effective solutions to societal challenges” (DeLosRíos-White et al., 2020, p. 2), or as more cost-effective than “traditional” approaches (Kabisch et al., 2016; Depietri & McPhearson, 2017).

However, few NbS papers under review provided quantitative or other justifications for this cost-effective framing, instead appealing to general knowledge and provided definitions of “nature-based solutions.” Those that more closely analysed this potential characteristic came to mixed conclusions: Seddon et al. (2020), for example, outline the challenges of estimating the holistic costs and benefits of NbS, including the relative timescales of costs and benefits, the difficulty of modeling associated co-benefits, and more. In a comprehensive analysis of NbS for adaptation, Chausson et al. (2020) note that only two studies examined included cost-benefit comparisons between NBS and engineered approaches. Multiple authors recommended further research on the cost-effectiveness question, emphasizing the need for a more sound evidence base to support deployment of NbS for adaptation (Kabisch et al., 2016; Chausson et al., 2020).

3.2.3 Maturity/effectiveness

In the literature under review, natural solutions were also frequently depicted as mature, effective, or readily deployable actions in contrast to more traditional solutions. This framing was especially prevalent in the literature on NCS, where natural solutions were contrasted with negative emissions technologies such as BECCS. (In contrast, it could be argued that engineered solutions for climate adaptation – such as sea walls or other “grey” infrastructures – have been more widely tested and widely used than their “natural” counterparts; see Seddon et al. (2020).) According to Griscom et al. (2017, p. 11647), land stewardship – which underlies most of the examples given of NCS – is the most mature carbon dioxide removal (CDR) option available to policymakers, and critiques negative emissions technologies that remain “decades from maturity”. Fargione et al. (2018, p. 1) similarly argue that natural solutions are mature “compared to nascent carbon capture technologies”, and Qin et al. (2021, p. 215) say that NCS have “consistently been promoted as one of the most effective, readily available mitigation options.”

This “maturity” framing of NCS, however, is still under contestation. While the claim that “natural” negative emissions technologies have been more thoroughly tested than more “speculative” technologies such as BECCS is not uncommon – (see for example Field & Mach, 2017) – it is not a consensus view across all potential NCS proposed. For example, in some analyses, measures that are considered NCS, such as biochar, have been rated as similar in readiness to “unnatural” solutions such as BECCS, direct air capture, or enhanced weathering (Minx et al., 2018). Some of the NCS literature under review also questioned the permanence or effectiveness of these solutions due to temporal considerations. Qin et al. (2021), for example, point to delayed action as a factor hindering the efficacy and uptake of NCS, while others highlighted the risks of climate change or future land disturbance causing a loss of carbon stocks (Kalt et al., 2019; Crusius, 2020). This effect was partly mirrored in the NbS literature, where several authors pointed to knowledge gaps in analysing their efficacy or miscommunication around the applicability of particular solutions. Tree-planting, for example, viewed as a critical NbS or NCS for mitigation, was critiqued by some papers under review as ineffective, particularly in the form of plantations or monocultures (Fleischman et al., 2020; Seddon et al., 2021).

3.2.4 Governance

Natural solutions were also framed in the articles under review as requiring different patterns of governance than more engineered, or technical, climate solutions. Particularly in the literature on NbS, it was argued that natural solutions require multi-sectoral investment and leadership, as their management may cut across local and national governments and require cooperation and coordination from a mix of different stakeholders (Kabisch et al., 2016; Nesshöver et al., 2017; Calliari et al., 2019; Seddon, Chausson, et al., 2020). Some suggested that because NbS have the potential to connect local people with natural resources, the use of participatory processes and consultations is critically important (Nesshöver et al., 2017). Thus, in contrast to more engineered solutions – which are generally viewed as more technocratic interventions (Eggermont et al., 2015) – natural solutions were seen as requiring decentralized governance regimes and multidisciplinary approaches. Particularly in the case of urban environments, scholars argued that NbS require local governments to act in concert with local community groups, NGOs, and scientists (Frantzeskaki, 2019). Pauleit et al. (2017, p. 3), for example, argue that NbS should be distinguished from "more traditional and top-down conservation", owing to its engagement with participatory processes of co-design and co-management. This is part of a wider movement towards distributed governance and management other NbS-related concepts, such as ecosystem-based adaptation or green and blue infrastructure. Some have suggested that NbS may, in fact, facilitate, and not only make use of, the construction of broader and more decentralized management regimes, in which authority over natural resources is devolved to a wider range of actors (Seddon, Chausson, et al., 2020).[4]

On the other hand, the NCS literature under review was largely silent about the possible governance requirements of natural solutions as alternatives to other negative emissions technologies. The exceptions were Fleischman et al. (2020) and Townsend et al. (2020) (the latter utilized the terminology of NbS but focused exclusively on climate mitigation). Both authors argued that existing natural solutions, particularly afforestation, have not sufficiently incorporated rural and

[4] There were a couple of notable exceptions to this trend in NbS literature reviewed -- one paper suggested that citizen engagement could actually hamper sustainable outcomes of urban NbS (Wamsler, Alkan-Olsson, et al., 2020).

indigenous people in planning and management – thus undermining the effectiveness of the intervention (Fleischman et al., 2020; Townsend et al., 2020).

3.2.5 Natural or "unnatural" solutions?

Table 5 illustrates the primary appraisal framings of natural solutions to climate change that appeared in the literature reviewed, and (where applicable) how technological, alternative, or technological solutions were presented in contrast. In some cases, the contrast between "natural" and "unnatural" solutions was depicted explicitly (e.g., contrasting the maturity of NCS in comparison to BECCS); in other cases, the contrast was implicit, existing in the background of justifications for pursuing these particular solutions. The available literature on NbS, it should be noted, appeared to be more reflexive, including more extensive caveats and clarifications on these framings overall, while the NCS literature adopted many of these framings (especially co-benefits and maturity) as given. This may not be surprising given the early stage of NCS literature, which effectively began with the term's coinage by Griscom et al. (2017). However, that was not always the case: The NbS literature examined also prominently "cost-effectiveness" as a justification for natural solutions, building on claims from the IUCN and European Commission, but included few critiques or detailed examinations of the relative cost of traditional vs. natural solutions.

Table 5. Framings of natural solutions to climate change.

	Natural solutions	**Unnatural solutions**
Co-benefits	Many	Few, or negative
Cost	Cost-effective	Expensive
Feasibility/maturity	Already tested, mature	Speculative
Governance	Decentralized	Technocratic

Few of the 33 papers reviewed were reflexive about the definition and inclusivity of the term "nature" and which solutions should count as "nature-based" or "natural" (notable exceptions include Eggermont et al., 2015; Nesshöver et al., 2017). Griscom et al. (2017), for example, simply characterize natural climate solutions as "conservation, restoration, and improved land management actions", without further explication. Many works under review did not provide explanation for the inclusion of particular types of solutions which incorporate "nature" and the exclusion of others; although there was a growing awareness in the literature that some so-called "natural" solutions might in fact be poor for biodiversity and thus should be reconsidered for inclusion (Fleischman et al., 2020; Seddon, Chausson, et al., 2020). The most reflexive examination of NbS and NCS boundary-setting came from Nesshöver et al. (2017, p. 1220), who noted that "engaging in pluralistic reflection about alternative framings and conceptualizations" of natural solutions can be useful for setting expectations and, indeed, identifying NbS in the first place.

These "unnatural" vs. "natural" distinctions among solutions could structure the way that policymakers respond to and understand the complexities of available climate policy options. In the following section, we discuss the theoretical and practical implications of these framings and how they may ultimately shape public and political responses to this select group of climate solutions.

4. DISCUSSION

4.1 'Nature' in climate change solutions

The concept of nature is both socially mediated and historically specific, even as it ostensibly signifies phenomena that exist regardless of how they are conceived. Nature can be seen as an external presence separate from human activity and society (essentially, the environment), as an internal quality (the nature of object, event or process), or as a universal and ubiquitous force that orders both humans and non-humans (Castree, 2005, 2014). These definitions of nature also inhabit particular realms of cultural thought: In Enlightenment thinking, for example, nature is a set of laws or physical processes that can be discovered, managed, and manipulated for human ends; in Romanticism, meanwhile, nature is external, pure, and pristine, and must be conserved and protected from human infringement (Macnaghten & Urry, 1998). This latter framing persists in parts of the environmental movement and in society at large: Nature is often seen as being intrinsically good, ideal, and in need of human protection. According to Williams (1983, p. 223), "one of the most powerful uses of nature, since the late 18th century, has been in this selective sense of goodness and innocence". This framing also renders nature a powerful political tool – according to Hansen (2006, p. 813): "Invoking 'nature' serves to inoculate against criticism or further scrutiny and to invest partisan arguments and interests with moral or universal authority and legitimacy."

Indeed, there is growing understanding that assigning a particular policy or action the label of "natural" can serve to elide other considerations and forms of analysis. By calling some actions "natural" – and implicitly dubbing others as "unnatural" – attention can be diverted from the actual qualities of a policy and replaced with a general sense of the "goodness" or "rightness" of such interventions (Hansen, 2006). The highly abstract semantics of 'nature' can subsume the important particularities of a policy or set of place-based interventions. For example, members of the public generally respond positively to products or measures that appear natural, and negatively to those that they perceive as unnatural – such as include genetically modified foods or some types of geoengineering (Corner et al., 2013; Hansen, 2006). That is why, some including Uggla (2010, p. 79), argue that: "Instead of searching for nature and the natural, we should view these concepts as political, and analyze the implications of particular definitions and their applications."

Natural or nature-based solutions provide a particularly salient example of how the concept of "nature" can be leveraged for particular sociopolitical ends. NbS and NCS appear to be descended from two existing framings of "nature" that have become widespread in environmental policy and activism. The first is the Romantic idealism mentioned above, in which nature is considered pristine, good, and possessed of valuable extra-social qualities. The second is what Macnaghten and Urry (1998) call "environmental instrumentalism", or the belief that nature should be protected, but for anthropocentric reasons – in order to attain particular individual or collective goods. These framings combine fruitfully with the longstanding view of climate change as a phenomenon that runs counter to nature. The environmental activist and writer Bill McKibben, for example, famously argued that climate change represented "the end of nature" – for him, the purity of wilderness was forever lost due to greenhouse gas emissions (McKibben, 1989). Against this backdrop, natural solutions promise to kill two birds with one stone. According to many scientists who encourage their use, they can restore individual ecosystems to more natural states, while simultaneously returning the climate system as a whole to a more natural and habitable state.

But the "naturalness" of natural solutions should be seen as political, and thus contestable. This is visible in some of the debates around what counts as a natural solution and what may not. Seddon, Chausson, et al. (2020), for example, suggest that non-native monocultures – although they may satisfy the definition of NbS broadly writ – would not come with the same benefits for ecosystem services as more ecologically and biodiversity-mindful interventions. Some climate solutions, meanwhile, particularly those related to geoengineering or CDR, have long been framed as tampering or messing with nature (Corner et al., 2013) – these options are mostly left out of the NbS and NCS typology, although some of them do have certain similarities with measures that are considered "natural". Lingering questions about whether genetically modified organisms, or ecosystems created by humans, should count as natural solutions also show the slippage and flexibility of these definitions of nature.

4.2 Natural solutions and their attendant framings

Meanwhile, in many cases natural solutions are presented as explicit (and often, superior) alternatives to more technological, or engineered solutions; they are also often seen as relatively mature, low-cost, accompanied by substantive co-benefits, and governable in a more democratic, decentralized way. These framings – which may indeed be associated with some, or even many, natural solutions – are often described as universally applicable to all natural solutions. It would be wise, however, to unpick which of these framings are actually associated with the policy proposed, and which are piggybacking on the umbrella concept of "natural," which is known to carry positive connotations and associations for the public and those in the environmental movement (Sjöberg, 2000; Corner et al., 2013). Labeling a solution as "natural" should thus be seen as a way of highlighting some climate solutions – and imbuing them with particular value-laden frames of efficacy or maturity – while eliding or ignoring others. In turn, such frames serve to legitimize certain solutions while delegitimizing others, with political implications (Kreuter, 2021). The result may be a questionable binary choice between desirable "natural" solutions and undesirable solutions that are explicitly or implicitly labeled as "unnatural". The danger is that by recasting climate solutions in this simplistic but powerful way, the range of policy options deemed attractive to policymakers will be significantly narrowed. This is problematic for at least three key reasons.

First, natural solutions may not be as desirable as they might first appear. Much like the more traditional, solutions they have been framed in contrast with, their co-benefits may be counterbalanced by or even outweighed by negative impacts. Many natural solutions require significant amounts of land area, which may result in both direct and indirect land use changes, while at the same time risking livelihoods, biodiversity and food security. They may pose risks to human health through allergens and the spreading of infectious diseases (Nesshöver et al., 2017). What is more, even their main claimed benefits may be in doubt. Take, for example, the recent controversy surrounding estimates that afforestation alone could sequester 205 gigatonnes of carbon at maturity (Bastin et al., 2019), which has now been shown to be an estimate approximately five times too large (Veldman et al., 2019). Natural solutions may also be expensive. Biochar burial, for example, could cost up to $200 per tonne of carbon dioxide removed from the atmosphere. At best, cost estimates remain highly uncertain over long timescales and in modelling co-benefits (Seddon, Chausson, et al., 2020). Natural solutions to climate change may also be far more immature and speculative than their advocates might like to admit. For example, wetland, peatland and coastal habitat restorations and biochar burial exist only at middle-to-low technology readiness levels of between 5-6 and 3-6, respectively (Royal Society and Royal Academy of Engineering, 2018). Compared to other, more technological, climate solutions, they are also subject to greater uncertainties around the monitoring, reporting and verification of greenhouse gas stocks and fluxes (ibid). Moreover, the governance of natural solutions to climate change may be just as open to technocratic forms of governance as their ostensibly “unnatural” counterparts. To illustrate, we need look no further than the top-down, centralized and technocratic environmental management regimes that are widely found in colonial and post-colonial tropical countries (Halik et al., 2018).

Second, the narrowing of policy options deemed attractive to policymakers facilitated by the natural framing is potentially problematic because it deliberately, inadvertently or tacitly marginalizes alternative climate solutions. And just as natural climate solutions may turn out to not be as desirable as they first appear, those solutions tacitly labelled as ‘unnatural’ may transpire to be more desirable than they first appear. They too may have significant co-benefits. Compared to “natural” solutions they bring a greater permanence of stored carbon, economic diversification and more business opportunities, as well as opportunities for technology transfer (Minx et al., 2018). BECCS produces energy as well as fostering energy independence, while direct air capture requires very little land space and could have applications in indoor air quality improvements (ibid). Similarly, they may also be cost-effective. For example, the costs of building with biomass are negligible in most applications (McLaren, 2012). Low carbon concrete and enhanced weathering could cost as low as $50 per tonne of carbon dioxide removed from the atmosphere, and direct air capture could fall as low as $100 per tonne in the longer term (Royal Society and Royal Academy of Engineering, 2018). ‘Unnatural’ climate solutions may also be far more tested and mature than their critics might like to admit.

According to one estimate, building with biomass, for example, exists at a high technology readiness level of 8-9 while BECCS, direct air capture, and low carbon concrete exist at middle-to-high technology readiness levels of 4-9, 4-7, and 6-7, respectively (ibid). The governance of unnatural solutions to climate change may also be just as open to decentralized forms of governance as their ostensibly natural counterparts. The literature on governance for CDR – natural and unnatural alike – is increasingly recognizing the need for decentralized approaches "from the ground up" (Bellamy & Geden, 2019), together with societally and geographically sensitive input on their designs (Bellamy, 2018; Buck, 2018).

Finally, the concept of "natural solutions" is not only bound up with these various qualities of climate solutions – it is also associated with the many meanings and social connotations carried by the label "natural", including, as described above, concepts of goodness, rightness, or even innocence and purity. As one of us notes elsewhere (Castree, 2014, p. 9, 2021), "nature" can be thought of as a keyword that is "able to govern (i.e. steer or direct) not only our thinking but also a wide range of practices resulting therefrom." The association of particular policies with the idea of "nature" may thus trigger a whole set of unconscious or unstated implications in the minds of policymakers, which could be mixed, occluded, and otherwise entangled with the characteristics of the solutions themselves.

4.3 Recommendations and further research

The "natural" framing thus powerfully obscures such underlying ambiguities and uncertainties about the efficacy of different climate solutions. This risks creating an asymmetry in the way climate solutions are evaluated as policy options, whereby pre-given assumptions around aspects of performance render natural solutions subject to lower standards of approval or else more likely to be seen as optimal. This restricted representation – or unreflectiveness – threatens to unduly close down the range of options in climate policy. To avoid this, the framing of natural solutions must be "broadened out" to more diverse representations and "opened up" to critical reflection (Stirling, 2008), both in terms of their labelling and their substantive appraisal.

First, the labelling of climate solutions as "natural" must be recognized as a form of "boundary work"; the active process by which people define and delimit the contours of a social phenomenon (Gieryn, 1983). The selection of which climate solutions should be considered "natural" should therefore be seen as a political act, whereby particular solutions are elevated and or privileged over others. Therefore, instead of selecting policy options by their adherence to a “natural” label, policymakers and scientists should examine them for their particular characteristics alone, in context – thus broadening the range of potential policy options.

However, the manner in which those characteristics are judged and assessed should also be scrutinized. Appraisals of natural climate solutions must be recognized as “social processes through which knowledges are gathered and produced in order to inform decision making and wider institutional commitments” (Stirling et al., 2007, p. 1). The fact that appraisals are conditioned by social processes makes them susceptible to framing effects – the shaping of outcomes from the ways in which evaluators choose to organize and communicate their assessments. Key factors shaping the framing of appraisals include (but are by no means limited to): how problems are defined; what options are chosen; what criteria are selected; whose perspectives are included; how ambiguities and uncertainties are conveyed; and what methods are used. We have already seen how defining the problem as one to be solved by natural solutions forecloses alternatives, thereby limiting the range of options included in appraisals to only those that fit the narrow formulation of a “natural” solution. The criteria used to evaluate the options are similarly restricted to four mainly technical considerations: risks and benefits, costs, feasibility and governance. Accordingly, the perspectives included and methods employed have been predominantly technical in nature, such as computational modelling and economics. Ambiguities and uncertainties have been routinely downplayed, presenting natural solutions as unproblematically more beneficial, cheaper, mature, and decentralized. In short, existing appraisals of natural solutions use overly narrow and closed framings that marginalize alternative options, disregard social criteria, exclude diverse forms of expertise, employ reductive methods, and downplay incertitude. These framings serve to make natural solutions appear to be the optimal choice.

The problem is, of course, that natural solutions may only appear to be optimal under the narrow set of framings upon which their apparent optimality is based. To engender more robust forms of decision making, the inputs to appraisals of natural solutions must be broadened out and their outputs must be opened up. To the incumbent technical criteria, we can highlight a plethora of more social criteria that have been largely absent from appraisals thus far, including political, cultural, and ethical dimensions. To facilitate this expansion of considerations the range of perspectives must be also expanded to include participation from the social sciences and humanities, as well as wider stakeholders and the public. In turn, this requires more reflexive methods of appraisal be utilized, ones that are able to accommodate diverse framings and represent ambiguities and uncertainties. A number of such appraisal methods are available, including Q-method, scenarios workshops, open space, multi-criteria mapping and deliberative mapping, some of which have already been deployed in relation to NCS; although much like the conversation on NCS governance, have taken place in the CDR and/or climate geoengineering literature (Bellamy et al., 2013; Cairns & Stirling, 2014; Bellamy et al., 2016). Accordingly, instead of leading to unitary and prescriptive policy recommendations that promote more research and investment into particular solutions that appear preferable under narrow framings, this would lead to plural and conditional recommendations that are candid about the framings under which the solutions perform (Stirling, 2008). It may well be wise, in this context, to abandon the meta-distinction between natural and unnatural solutions altogether.

Moreover, this review has focused on the portrayal and framing of natural solutions for climate change in a (largely academic) systematically selected subset of the available literature; future research should examine the prevalence of these frames in a larger set of grey literature, in which a substantial amount of NbS/NCS research and commentary takes place – examining the level of reflexivity around definitions of “natural”, acceptance (or contestation) of dominant characteristics and justifications for natural solutions, and any other frames that may emerge. There is also a need to examine the discourse around natural solutions with respect to prominent actors and interests advocating their use; NbS and NCS can be seen as a way to elevate conservation goals within the focus on climate change, thus maintaining attention and (potentially) funding. Future researchers should undertake empirical work to understand the role of these actors and networks in facilitating the research and development of NbS in relationship to other climate solutions.

Conclusion

Recent interest in natural solutions to climate change is part of a longer history in policymaking around “natural”, “nature-based”, or “ecosystem-based” solutions for mitigation and adaptation, dating back to the rise of ecosystem services scholarship in the 1980s. Natural solutions to climate change come in two distinct yet interconnected types: NbS and NCS. NbS is often used as an umbrella concept and is broader in scope, including mitigation and adaptation strategies, while NCS is much narrower, concerning the reduction or removal of carbon dioxide in the atmosphere only. The nature of both types of natural solution is ambiguous and contested, however, with various different attempts at demarcating where the lines should be drawn on what constitutes a natural intervention and what is instead unnatural. A suite of attendant framings come with these demarcations in the appraisal of climate solutions, with natural policy options seen as more beneficial, cost effective, mature, and decentralized than their unnatural counterparts.

The definition and framing of natural solutions to climate change can be explained by the persistence and prevalence of the Romantic view in which nature is seen at some level as still external, pure, and pristine, and in need of conservation and protection from human activities. And yet, the nature of natural solutions is not so clear cut – nature is socially constructed in discourse and imbued with sociopolitical associations. The result – or rather risk - therefore is a false binary choice between ostensibly natural and ostensibly unnatural solutions. What is more, the naturalness of a solution is well known to be a significant predictor of positive public opinion. The danger is that the range of policy options deemed attractive to policymakers will be significantly narrowed. This is problematic because 1) upon closer scrutiny natural solutions may not be as desirable as they first appear, and 2) unnatural solutions which may be more desirable than they first appear are marginalized. To avoid this, we call for researchers and policymakers to resist the presently narrow conceptualizations of natural solutions and instead embrace more open understandings of nature. In parallel, we recommend that the framing of appraisals of natural solutions be broadened out and opened up to diversity and reflexivity. Indeed, idealistic though it is, it may be advisable to dispense with the concept of nature entirely when considering environmental management in the 21st century, at least at the global scale. It is too abstract and, despite its semantic complexities, of limited use if we are to understand a thoroughly hybrid Anthropocene reality.

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