The Global Governance of Climate Change through Nature-Based Solutions

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Abstract

This Major Paper is on the global governance of climate change through nature-based solutions (NbS). It explores how nature-based solutions (NbS) support the realization of the 1.5-2°C target of the Paris Agreement on climate change, as well as the global environmental and societal goals reflected in the UN 2030 Agenda's Sustainable Development Goals and under the UN Convention on Biological Diversity. To do so it first reviews the evolution of the conceptualization of the term NbS from 2008 to the present. From here it conducts a scoping review of the NbS literature, with a focus on climate change and governance. It presents the key governance opportunities, barriers and challenges, and recommendations for overcoming these challenges that the peer-reviewed literature emphasizes. The overarching takeaway inferred from this review is that due to nature's inherent multifunctionality and cost-effectiveness, NbS can be highly effective for meeting global climate and societal goals if NbS implementation is guided by sound global principles and standards that allow for the use of a range of regionally or locally-appropriate assessment frameworks based on best practices, and if multilevel and multi-actor collaborative governance is modelled. In this event, NbS can be a powerful approach with wide-reaching effects for emissions abatement and resilient and sustainable societies. In all, this Major Paper explores how NbS can help build a holistic and more equitable society and future, alongside commonly used terms such as technical- and market-based solutions.

Foreword

This Major Paper is on the global governance of climate change through nature-based solutions (NbS). In all it seeks to explore how the conceptualization of nature as NbS supports the realization of global climate change and societal goals, particularly those set out in the Paris Agreement on climate change and in the UN 2030 Agenda's Sustainable Development Goals. To do so it reviews the evolution of the conceptualization of NbS, with a complementary scoping review of the opportunities and challenges of NbS implementation. With its focus on effectiveness and its approach within a global governance context, this Major Paper adds coherence to my overall Plan of Study on the topic of Global Climate Change and Environmental Governance. My Plan of Study explores the history of global climate change and environmental governance, the global climate change and environmental governance landscape, including key actors and institutions, and issues related to accountability and effectiveness. Similarly, this Major Paper explores the history of NbS for climate change and engages with the concepts of multilateral and polycentric governance as a lens through which to understand the global to local linkages within the global climate change governance landscape. This Major Paper is therefore presented in partial fulfillment of the requirements for the degree of Master of Environmental Studies at York University.

Contents

Abbreviations

COP	Conference of the Parties
EC	European Commission
EU	European Union
G7	Group of Seven
G20	Group of 20
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for the Conservation of Nature
MAES	Mapping and Assessment of Ecosystems framework
LULUCF	Land use, land-use change and forestry sector
NbS	Nature-based Solutions
NGO	Non-governmental organizations
REDD+	Reducing emissions from deforestation and degradation
SDG	Sustainable Development Goals (2030 Agenda)
UN	United Nations
UNCBD	UN Convention on Biological Diversity
UNDRIP	UN Declaration on the Rights of Indigenous Peoples
UNFCCC	UN Framework Convention on Climate Change

1.0 Introduction

The concept "nature-based solutions" (NbS) was coined by the World Bank in 2008 (World Bank 2008). It has since become a core program area within the International Union for the Conservation of Nature (IUCN) and the European Union (EU) (IUCN 2009, 2012, 2020; EC 2015, 2020). Since 2015, after the European Commission (EC) put forward a definition for NbS, there has been an increase in the use of the term NbS and on the conceptualization of NbS in research (Mendes et al. 2019). In light of this "mainstreaming" of NbS in global governance and in research, this paper conducts a scoping review of the literature on NbS with the purpose of casting light on the current state of the discussions regarding the potential of nature-based solutions' contribution to global climate change governance. Meeting global climate change goals is a core objective of NbS making it significant within the global climate change governance regime. This paper synthesizes the NbS literature on climate change and governance, by presenting the governance opportunities, barriers and recommendations for the effective implementation of NbS.

The NbS literature is discussed in the context of an increasingly interconnected and globalized world (Kirton 2013), where some scholars argue that the global governance of climate change has evolved from a state-centric system to a networked, multilevel, polycentric system, within which nonstate actors hold increasing influence (Abbott 2012; Bäckstrand et al. 2017; Boran 2019). Within this system the shared global climate goal is to hold "the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels…" (Paris Agreement 2015, 3). The global climate agreement to strive for a 1.5°C target was made in recognition that "this would significantly reduce the risks and impacts of climate change" (Paris Agreement 2015, 3). According to a review of ~70 peer-reviewed

climate studies, the impacts of climate change are worse across almost all indicators in a 2°C compared to a 1.5°C world (Carbon Brief 2018). Despite this, emissions continue to rise unabated (UNEP 2019). The Intergovernmental Panel on Climate Change (IPCC) warns with high confidence that the world is "likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate" (IPCC 2018, 4). This suggests an immediate need to scale-up resiliency efforts in the increasingly likely event of a 1.5°C world, while also not losing sight of the need to increase ambition to abate emissions growth.

Although there is no silver bullet solution to the climate crisis, one often overlooked approach to achieving global climate change goals are nature-based solutions. Nature has been valued by many cultures throughout history for the ecosystem and cultural services it provides, but only recently has a broad concept for meeting global climate change and socioeconomic goals been developed (World Bank 2008; IUCN 2009). The two leading definitions are from the EC (2015) and IUCN (2016), with the latter focused on conservation and the former on greening European cities. Both agree that NbS is an umbrella term that encompasses but does not replace existing nature-based approaches (such as ecosystem-based mitigation or green infrastructure). Yet the term has raised concerns within the literature over what should count as an NbS and over the potential for greenwashing (Nesshöver et al. 2017; Seddon et al. 2020). Despite these concerns, the literature seems to agree that an effective NbS must provide social benefits to the community and that to do so requires a multi-actor, multilevel approach to governance, with an emphasis on local engagement (Bush et al. 2019; Mendes et al. 2019; Pederson Zari et al. 2019). This aligns with the view of the global climate change governance landscape as an increasingly polycentric system.

The emphasis in the literature on social benefits underscores the comparative advantage of NbS over the more dominant technical- and market-based solutions. While technical-based solutions tend to focus on a single technical problem, nature-based solutions are multifunctional and therefore support the realization of social goals, as well as climate and environmental goals (Albert et al. 2019). These social goals are captured in the UN 2030 Agenda's 17 Sustainable Development Goals (SDGs) and 169 targets (UNDP 2020). Some societal SDGs that NbS contribute to include zero hunger (SDG2), good health and well-being (SDG3), decent work (SDG8), reduced inequalities (SDG10), sustainable cities and communities (SDG11), strong institutions (SDG16) and partnerships for the goals (SDG17). On biodiversity goals, the SDGs include life below water (SDG14) and life on land (SDG15). These are linked to the 2011-2020 Aichi biodiversity targets under the UN Convention on Biological Diversity (UNCBD).[1]

Nevertheless, the literature identifies several barriers to implementation, including jurisdictional, financial, political and legal, and institutional barriers, along with challenges related to stakeholder engagement and trade-offs. A key caution in the literature is not to allow NbS to be used as a distraction for the major mitigation measures needed, namely the needed systemic and transformative shift away from the fossil fuel and intensive agriculture sectors to a sustainable, circular and more equitable system (Seddon et al. 2020). With this in mind, the literature calls for "radical systemic change" (Seddon et al. 2020) and "new" forms of governance and "holistic" approaches (Mendes et al. 2019).

Against this backdrop, this MAJOR PAPER explores how NbS can help build a holistic and more equitable society and future, alongside commonly used terms such as technical- and market-based

[1] At the time of writing a post-2020 global biodiversity framework was being negotiated (UNCBD 2020).

solutions. To do so it presents findings from a scoping review of the NbS literature on climate change and governance, with a focus on multilevel, or global to local linkages, and the effectiveness of NbS implementation.

2.0 Issues, Significance, Approach Methodology, Paper Outline

This chapter presents the overarching issue of climate change, its well-documented impacts, and the short time-line for which scientists predict irreversible environmental changes will occur (UNGA 2019). It then discusses the significance of nature, and of the term nature-based solutions, for facilitating a perspective change and, from that, the climate action needed to avoid the worst impacts of global heating, while building resiliency. From here, it discusses the approach this paper takes, followed by the methodology used for the scoping review (presented in Chapter Four). It ends with the paper outline.

2.1 Issues

The average global temperature is almost 1.3°C above pre-industrial levels (WMO 2019). This is dangerously close to the 1.5°C aspirational target agreed to by 194 countries in the 2015 Paris Agreement. This target is aspirational as the Paris Agreement states its goal as keeping "the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels…" (Paris Agreement 2015, 3). Yet if current national policies do not change, the 1.5°C target will be hit in a few years (IPCC 2016). As that there is little indication of such a policy change today, it is increasingly likely that this target will be surpassed. This reality means that attention needs to shift to meeting the Paris Agreement's target of avoiding a 2°C rise above pre-industrial levels, a number that scientifically symbolizes worst

case scenarios (IPCC 2018; Carbon Brief 2018), while simultaneously transforming our societies to be resilient to the realities of a 1.5°C world.

According to a review of ~70 peer-reviewed climate studies, the impacts of a 2°C world are almost always worse across all predictive indicators than in a 1.5°C world (Carbon Brief 2018). At 2°C, infectious diseases, like malaria, spread faster, and non-communicable diseases, like heat stroke, are more prevalent. At 2°C there are more people fleeing their countries and more people internally displaced, due to sea level rise that will create unlivable situations and exacerbate existing conflicts; there are more intense, more frequent and more unpredictable storms, with regional variations; there is more food and economic insecurity; and so on (Carbon Brief 2018). A 2°C world is predicted to trigger "runaway" climate change, whereby the aforementioned impacts, and more, are predicted by the scientific community to become irreversible (UNGA 2019). This outcome will be that much more difficult to live with and to adapt to. When climate scientists are wrong about their estimations and climate modelling, it is not typically due to overestimations but underestimations (Oreskes 2019). A 1.5°C world will still have sea level rise, storms and heightened socioeconomic problems. But the severity is predicted to be less, and therefore relatively more easily adapted to.

Climate change is a threat multiplier — it not only creates new but exacerbates existing challenges including biodiversity loss, equity, disease and poor health. It is therefore critical to take a holistic perspective when determining the most effective, efficient and equitable way to keep the global average temperature from tipping over the 2°C threshold. The literature on NbS and climate change calls for a multisectoral, multilevel, multi-actor and multidimensional approach. It calls for a multifunctional solution that can provide multiple benefits, while avoiding trade-offs.

2.2 Significance

Nature offers such a solution. NbS has emerged as a catch-all term that helps equate nature-based interventions to meeting global climate change and societal goals with more commonly used governance tools, namely technical-based and market-based solutions. Nature's comparative advantage over alternative technical- or market-based solutions is that nature is inherently adaptable and flexible to external environmental shocks, is inherently multifunctional, and therefore provides multiple co-benefits. As such, nature-based solutions are often found to be a more economical choice relative to technical solutions that tend to focus on a single outcome (Lafortezza et al. 2018; IPBES 2019). A highly salient co-benefit provided by nature is protection against the global spread of infectious diseases and promotion of overall health and well-being (Kabisch et al. 2016; Artmann 2018; Möller 2019). On climate mitigation, the Intergovernmental Panel on Biological Diversity and Ecosystem Services (IPBES) reports that nature has the potential to mitigate almost 40% of global greenhouse gas (GHG) emissions (IPBES 2019). Nature-based interventions strongly support vulnerability and disaster risk reduction and therefore increased resilience and adaptive capacity across different landscapes (Santiago Fink 2016; Bush and Doyon 2019; Möller 2019; Pagano et al. 2019; Seddon et al. 2020). Yet nature has been overshadowed by technical- and market-based approaches, in no small part due to the environment's status as an externality within the current conventional economic system (Rockström 2017).

2.3 Approach

This paper views NbS in the context of an increasingly globalized world where intersecting crises are merging together, where international institutional multilateralism and cooperation is fraying, and where long-term global economic stability seems increasingly elusive. This paper is written at a time of unprecedented global prosperity and technological and scientific advancement juxtaposed against

unprecedented global wealth inequality and climatic and planetary instability, all caused by human choices and pursuits. It is written in a context of passionate opposing views to the distribution of the benefits and harms of capitalist-led globalization, alongside the intentional sowing of divisions and upholding of a status quo fuelled by fossil-based energy and a limitless linear growth-based model of intensive extraction, production, consumption and waste.

This paper incorporates a global-local, or multilevel, polycentric governance perspective. Climate change is a globally shared problem that intersects with every other globally shared problem, but often has distinctive geographical impacts all the way to the most local level. A global-local perspective is compatible with the subject of global climate change governance, as in today's globalized world it is no longer only the traditional state apparatus that is responsible for creating and governing climate change, although the role of state policy remains crucial (Abbott 2012; Hale 2016; Boran 2019). This paper therefore applies a "think globally, act locally" perspective (Wendling et al. 2018). Governance is understood as "a conscious 'steering' or shaping of activities throughout the full international system, making particular values prevail in the substantial order that results" (Kirton 2019, 3). In the context of this paper's approach, the "full international system" is interpreted as the full network and spectrum of actors and institutions that participate in steering action and values for climate action through NbS. This importantly and necessarily includes but is not limited to the state system.

2.4 Methodology of Scoping Review

To understand the potential of "nature-based solutions" for climate change governance and to be able to present the "lay of the land" on the academic research done on the global governance of NbS for climate change, a scoping review was conducted (Arksey and O'Malley 2005). A search of

the keyword "nature-based solutions" in Scopus, as well as in Mendeley, JStor, Google Scholar, York University Library and University of Toronto Library was done. Articles with "nature-based solutions" in its title, abstract and keywords were selected. Cognate terms for "nature-based solutions," such as nature-based approaches falling under the NbS umbrella (for example, ecosystem-based approaches, conservation or green infrastructure) were excluded in order to focus on the explicit use of the term "nature-based solutions" itself.

The next step was to ensure the selected articles were aligned with the topic of climate change governance by selecting those articles that 1. centred climate change and 2. discussed governance at any level. Thus a further keyword search of "climate change" in the title, abstract or keywords was done with the goal to include articles that strongly focused on climate change as either a core problem or as a core co-benefit within the article. Next, within these climate-focused articles, a keyword search of "governance," policy," "global," "international" and "multilevel" was conducted. This search was not restricted to the title, abstract or keywords, but extended to the body of the articles too, as restricting the article selection to articles solely focused on governance of NbS for climate change would diminish the richness of the review as too few articles met that criteria. However, articles that included these governance keywords only in the references list were excluded. Another scan for any articles that were accidentally included that did not explicitly use the term "nature-based solutions" but that were on climate change or nature governance were also purged. Articles that did not meet these climate or governance criteria but that were conceptually-focused were kept. Lastly, institutional articles were removed and set aside for background and contextual information. This was done in order to focus this review on academic peer-reviewed work from scholarly journals.

This process resulted in 33 peer-reviewed scholarly articles on the conceptualization of NbS and on NbS to climate change with a governance aspect. Of these 33 articles, five were conceptual, 13 were on cities or the urban environment, four were on coastal resilience, four were on the water-climate nexus, three were country-specific case-studies, three were on stakeholder engagement, and one was on forests. All had a focus on NbS for climate change as a central goal or as a critical co-benefit. All linked their work with some aspect of governance.

2.5 Paper Outline

Before presenting the findings of the scoping review, Chapter Three reviews the origins and evolution of the conceptualization of NbS. It does so in chronological order, tracing the creation of the term in 2008-09, the formulation of global NbS principles in 2012, the formalization of NbS as a concept through the formulation of two overlapping but distinct definitions from 2014-2016, to the mainstreaming of NbS within the global governance landscape as demonstrated by its use within the Group of Seven (G7) and Group of 20 (G20) starting in 2018. Throughout, it engages with key academic debates. Chapter Four presents the findings of the review of the selected articles. A presentation of governance opportunities of NbS to climate change and barriers, is followed by an overview of recommended solutions for overcoming these barriers and thus for maximizing opportunities. It ends with a discussion on implementation and effectiveness in the context of keeping global climate commitments and the global-local governance links. A snapshot of the key findings of the reviewed articles are summarized in Appendix A and B. Lastly, Chapter Five concludes the paper.

3.0 The History and Evolution of the Conceptualization of Nature-based Solutions

This chapter reviews the origins and evolution of the term nature-based solutions, starting in 2008-09 until the present. A definition for NbS was first put forward in 2015 by the European Union and soon after in 2016 by the International Union for the Conservation of Nature. While other definitions have been put forward (Sarabi et al. 2019), those offered by the EU and IUCN are the most cited ones in the literature. The distinction between these two definitions serves to represent two ends of a spectrum of what could count as an NbS. The IUCN primarily focuses on conservation and the EU primarily focuses on green infrastructure in urban areas, while appearing to keep the door open for including biomimicry as an NbS. Since these regional and international definitions emerged, there has been an increase in attention within academia to discuss and develop the conceptualization of NbS (Mendes et al. 2019), along with a growing use of the term in global governance institutions, with NbS appearing on the G7 and G20 agendas in 2018 and 2019, respectively.

3.1. The Foundations of the Conceptualization of Nature-based Solutions as a Concept: 2008-09

The term nature-based solutions was first used by the World Bank in 2008 in a report it submitted to the IUCN's World Conservation Conference (World Bank 2008; Kabisch et al. 2016). The IUCN subsequently began using the term in 2009, in a submission to the 15th Conference of the Parties (COP 15) to the UN Framework Convention on Climate Change (UNFCCC) held in December 2009 (IUCN 2009). Neither institution offered a definition, but used NbS intuitively to make the conservation-climate link. In their reports both institutions centred the land use, land-use change and forestry sector (LULUCF), with a strong emphasis and focus on reducing emissions from

deforestation and degradation (REDD+), a regime established under the UNFCCC umbrella.[2] The LULUCF sector accounts for up to 37% of global emissions, when including the pre- and post-production of the global food system (IPCC 2020). With the conservation-climate link at the core, both institutions emphasized the co-benefits of protecting nature and of sound land management. The World Bank's report highlighted food, health and economic security, and cultural and spiritual benefits. The IUCN added adaptation benefits to the mitigation ones emphasized by REDD+, and emphasized the need for gender equality and women's involvement in decision making. An additional benefit was the potential relative cost-effectiveness of NbS to technical or engineered alternatives, in large part due to these co-benefits and ecosystem services provided by nature.

In NbS implementation, both institutions called for the inclusion of and partnership at all levels of government, from local communities and cities, to states and regions, to global multilateral intergovernmental institutions, as well as women, academia, non-governmental organizations. They also called for inclusion of Indigenous peoples, including the recognition of Indigenous land rights and the UN Declaration on the Rights of Indigenous Peoples (UNDRIP). They acknowledged the links between Indigenous land stewardship and biodiversity benefits.

Lastly, both institutions focused on NbS for the Global South. The World Bank, as a global development institution, introduced its report by aligning its position on NbS with its stated mission to alleviate poverty in developing countries. It also invoked global climate financing mechanisms designed to facilitate the flow of funds from developed to developing countries, such as the Global

[2] The World Bank also referenced the energy sector in its report, problematizing the framing of large-scale hydro dams and biofuels as alternative sources of energy due to their negative impact on local ecosystems and communities.

Environment Facility, as key implementation partners. The IUCN similarly centred Southern tropical countries' forests, and less developed Northern countries' deciduous forests.

These elements of conservation, co-benefits, cost-effectiveness and collaboration formed the foundational elements for the conceptualization of NbS. Each of these elements continued to be central, but the conservation focus on ecosystem-based mitigation and adaptation would expand to consider the increasing challenges presented by globalization, with rapid population growth and its concentration in urban centres a growing priority. This therefore included an expansion to include Northern industrialized economies.

3.2. The Formulation of Global Principles for Nature-based Solutions: 2012

In the following years, the IUCN advanced the conceptualization of NbS. In its 2012-2016 work program, the IUCN made NbS for climate mitigation and adaptation the third of three pillars (IUCN 2012). This pillar focused on ecosystem-based mitigation and adaptation, again with REDD+ at the core. There was therefore a continued conservation focus, in line with the IUCN's mission. Yet the IUCN also expressed the need to move NbS beyond the conservation community, with the objective to add coherency and consistency to a complex issue. Here it recognized nature's role in meeting global climate change and socioeconomic goals, highlighting food security and development as its focus, and health and energy access as areas of future work.

The IUCN also established eight preliminary principles for implementing NbS. The principles are grounded in conservation, integration with other solutions, coordination and collaboration with local/traditional communities, provision of societal benefits, maintenance of biodiversity and cultural diversity over time, application at the landscape scale, recognition of trade-offs, and

recognition of NbS as integral to the design of policies. These principles align with principles within existing approaches, such as ecosystem-based mitigation and adaptation, and add three novel ones of integration, a focus on the landscape scale, and coordination and collaboration in the context of complexity (Cohen-Shacham et al. 2019). The principles have been criticized for lacking four key elements of uncertainty, long-term stability, monitoring, and ecosystem complexity and temporal dynamics (Cohen-Shacham et al. 2019).

3.3. Defining NbS: 2014-2016

Based on this work, in 2016 the IUCN defined NbS as "actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively, simultaneously providing human well-being and biodiversity benefits" (IUCN 2019). Prior to this the EU began to lay its own groundwork for NbS at the regional level. In 2014, the EU established a working group on Nature-based Solutions and Re-naturing Cities under its Horizon 2020 innovation and research program (EC 2015). Thus NbS was framed from an innovation perspective rather than a conservation perspective, and the focus shifted from rural/tropical/forested areas to urban areas. Moreover, the focus was on European cities, so the geographical focus was also extended to include industrialized economies in the Global North. The Re-Naturing Cities report defined NbS as "solutions that aim to help societies address a variety of environmental, social and economic challenges in sustainable ways," adding that these solutions can be "inspired by, supported by or copied from nature" (EC 2015, 5).[3]

[3] The full EC definition of NbS: "Nature-based solutions aim to help societies address a variety of environmental, social and economic challenges in sustainable ways (EC 2015, 5). They are actions which are inspired by, supported by or copied from nature. Some involve using and enhancing existing natural solutions to challenges, while others are exploring more novel solutions, for example mimicking how non-human organisms and communities cope with environmental extremes. Nature-based solutions use the features and complex system processes of nature, such as its ability to store carbon and regulate water flow, in order to achieve desired outcomes, such as reduced disaster risk, improved human well-being and socially inclusive green growth. Maintaining and enhancing natural capital, therefore, is of crucial importance, as it forms

These IUCN and EU definitions, along with the EU call for research on NbS (EC 2020a), spurred academic discussion and debate on what counts as an NbS and on the usefulness of NbS as a new concept. The primary debate on what counts as an NbS relates to the EU's openness to including biomimicry as an NbS, which the IUCN rejects, as biomimicry mimics nature but does not necessarily include nature in its physical design. There is therefore a green vs. grey debate in the literature, with much of the work on NbS advocating for more nature and arguing that nature and green infrastructure outperforms grey infrastructure. Common examples cited to support this argument include on coastal protection, where studies find that natural greenery, such as mangroves and seagrass, does a better job of enhancing resilience to water-related disasters, such as sea level rise and tidal waves, than engineered alternatives (see for example Möller 2019). Urban based green infrastructure reduces the impact of heatwaves and storms and is "inherently more resilient than large, centralized grey infrastructure" (Bush and Doyon 2019, 3). An argument has also been put forward that the best approach is not an "either or" approach, but an integrated green-grey approach (Seddon et al. 2020). This recommendation was put forward in recognition of a growing consensus among practitioners, such as ecologists, engineers and managers, that an integrated approach may be most effective and that it could also support challenges related to diverging stakeholder interests.

This suggests that whether one takes the EU or IUCN definition could depend on the landscape and the local context where the NbS is being implemented. For example, an integrated grey-green approach may require greater consideration as an optimal option in cities where there is a large

the basis for implementing solutions. These nature-based solutions ideally are energy and resource-efficient, and resilient to change, but to be successful they must be adapted to local conditions."

concentration of people and where there is already a significant amount of grey infrastructure. Such a hybrid approach may also better account for the trend towards global digitalization and smart cities, which raises the question of how to incorporate nature not only into concrete-filled cities but alongside the internet of things and artificial intelligence that are being increasingly embedded into citizens' everyday lives. Conversely, a grey-green hybrid approach may not make as much sense from a conservation or regeneration perspective, or from a rural or agricultural perspective, i.e. in areas and communities where there are fewer people spread out over larger areas. This points to a spectrum of what could count as an NbS, with scholars identifying different "types" of NbS (Hilde Eggermont et al. 2015).

Regardless, both definitions agree that the chosen nature-based intervention must benefit society in order to be considered as "NbS." This includes from the IUCN's perspective, which does not automatically include any conservation effort as an NbS (Cohen-Shacham 2019). This shared social focus implicates the UN's SDGs, whose indicators have been used in at least one study as a benchmark for measuring the effectiveness of NBS (Wendling et al. 2018), and which can serve as a focal point for linking the local effects of climate change with the global causes.

This discussion on what should count as an NbS leads to a second debate in the literature – the greenwashing debate. A potential example of greenwashing is if grey infrastructure is labelled as an NbS if it has some resilience or social benefits (see Lafortezza et al. 2018 which cites a case study that found social benefits arose from a hydro-dam project). Additionally, while greenwashing implies intentionality in order to benefit the user, such as to increase engagement and profits or to raise political capital, the challenge of having several definitions of NbS could also extend to unintentional misuses due to confusion over what should be included. For example, as biomimicry mimics nature

but does not require the incorporation of nature, biomimicry could be seen as watering down the NbS concept, even if it has its benefits in its own right. Moreover, the term NbS itself could be viewed as an inherently greenwashed concept that is seeking to replace or inadvertently overshadow existing concepts.

On this latter point, the literature and IUCN and EU definitions are clear that NbS is being conceptualized as an umbrella term that is not intended to overtake or replace any existing concept, but rather to add cohesiveness to these existing concepts by combining them all under a single umbrella. In this sense, NbS can be viewed as a useful communication tool that can help equate nature and nature-based approaches to the more cited and used approaches in global governance of "technical-based solutions" and "market-based solutions." These two latter terms are also used as umbrella concepts that embrace a number of related tools. Additionally, Carsten Nesshöver et al. (2017) argue that reflecting on alternative meanings of NbS is "useful for identifying what is meant by NBS and the expectations for 'solutions' in any particular context" and that "the existence of a variety of ways to frame and define the concept is not necessarily problematic, as long as each case makes explicit its rationale and particular interpretation of NBS" (p. 1220). These definitional debates suggest that it is highly important to have a clear vision and objective, grounded in overarching principles and standards, for any NbS project (Cohen-Shacham et al. 2019).

The work on global principles and standards has been led by the IUCN. In 2016, the IUCN launched a process of public consultation and feedback to develop a set of global standards to address concerns over effectiveness by fostering consensus on what should constitute a "good" nature-based solution, as well as to ensure the concept became more than just a general metaphor. The goal was to create a Global Standard for the Design and Verification of Nature-based Solutions

that would aid in determining whether a given nature-based intervention should qualify as "NbS," with efficiency, effectiveness and sustainability in mind. The official launch of the standards was scheduled for the IUCN's 2020 conference. At the time of writing, the 2020 conference was postponed to January 7-15, 2021, due to the COVID-19 global pandemic (IUCN 2020a). The question of effectiveness is a hot topic in the literature on NbS and is discussed in more detail in Chapter Four. However, a central observation is that a set of global principles and standards for NbS could help strengthen the global-local linkages of climate change governance through NbS. Yet, a globalized approach should not be equated with a homogenous approach, as flexible and adaptive governance are recommended in the literature (Mendes et al. 2019; Bush et al. 2019), as well as a multi-criteria approach for assessing the effectiveness of NbS for climate change (Seddon et al. 2020).

3.4: Extending the Global Reach of Nature-based Solutions to the G7 and G20: 2018 -2020

Recently, NbS has gained more momentum and has increased its global reach. This is demonstrated by the appearance of the concept of NbS on the G7 and G20 agendas. NbS first appeared on the G7 agenda at its 2018 Charlevoix Summit. The G20 followed suit, putting NbS on its agenda at its 2019 Osaka Summit and again for its 2020 Riyadh Summit scheduled for November 2020.[4] This appearance signalled another geographic expansion of the NbS concept, with the G20 including countries from every continent (including all G7 members). The G20 accounts for ~80% of global GHG emissions (UNEP 2019a) and, as such, its commitments, and compliance with them, matters greatly (Kirton and Kokotsis 2015).

[4] At the time of writing, U.S. president Donald Trump had not released an agenda for the 2020 Camp David Summit he was set to host.

Moreover, although economic-focused forums, both the G7 and G20 have been heavily involved in the global governance of climate change and the environment since they were created in 1975 and 2008, respectively. They therefore have a self-declared mandate to reduce their emissions and engage in global multilateral cooperation to that end. For example, in its early years, the G7 acknowledged the need to address environmental pollution from fossil fuel energy, to protect oceans from oil spills, and to protect forests from illegal logging. In 2008 and 2009, the G20 committed to a "green recovery" and to phase-out inefficient fossil fuel subsidies over the medium-term. Each institution's agenda has expanded to include a range of environmental and climate issues, such as climate financing, reducing emissions from transportation, phasing out hydrofluorocarbons under the Montreal Protocol, air and water pollution, marine litter and the link between plastics pollution and human health, biodiversity, and more. NbS is therefore well aligned with the G7/20 agendas.

The G7's first reference to NbS was at its 2018 Charlevoix Summit. In its Charlevoix Blueprint for Healthy Oceans, Seas and Resilient Coastal Communities, the G7 committed to "advocate for and support nature-based solutions, such as the protection and rehabilitation of wetlands, mangrove forests, seagrass beds and coral reefs" (G7 Charlevoix 2018). Yet preliminary average compliance in the year after this commitment was made was very low, at 32% (G7 Research Group 2020). This was due to the equal weighting of the four ecosystems specified in the commitment, and the requirement to both advocate for and support most (at least three of four) of those ecosystems for the G7 member to be able to achieve full compliance.[5] Thus the G7 member could not receive a compliant score for simply supporting any NbS.

[5] The methodology used for this compliance assessment is based on a three-point scale whereby each G7/20 member is given a +1 for full compliance, a 0 for partial compliance or a work in progress, and a -1 for insufficient of non-compliance, based on a set of criteria or general interpretive guidelines unique to each discrete commitment assessed (Global Governance Program 2020).

Related to NbS, at Charlevoix, also in the Healthy Oceans Blueprint, the G7 additionally committed to encourage the development of natural infrastructure, including through standards and best practices; to increase the capacity building for coastal resilience of small-island developing states; and to support women's equal participation in decision making for disaster risk reduction and recovery. Further, in the preamble to the Blueprint, the G7 "underscore[d] the importance of engaging and supporting all levels of government to develop and implement effective and innovative solutions." From this, it committed to promote collaborative partnerships, listing local, Indigenous, remote and small island communities, the private sector, international organizations, and civil society as partners, and women and youth as "agents of positive change."

In 2019, at the G20's Osaka Summit held on June 28-29, 2019, the G20 made its first reference to NbS. It appeared in its communiqué, in a commitment to "look into a wide range of clean technologies and approaches, including…nature-based solutions" (G20 Osaka 2019). It appeared in a section on climate change, that discussed both mitigation and adaptation, including disaster risk resilience, environmental pollution and biodiversity. This section recognized the need for climate action at all levels, including by non-state actors, and additionally committed to "look into" traditional and Indigenous knowledge. The G20 was therefore more tentative and less committed to NbS from a conservation perspective than the G7.

Yet the 2019 Osaka Summit was notable as the first G20 to hold a pre-summit environment ministers' meeting, a staple of the G7 meetings since 1992. The G20 environment ministers met alone and then jointly with the G20 energy ministers. Together the G20 environment and energy ministers made a joint, more concrete commitment "to promote…nature based solutions that have

multiple benefits" (G20 Energy and Environment Ministers' 2019). Additionally, the G20 environment ministers alone dedicated a section of the communiqué to ecosystem-based approaches to climate adaptation, wherein they recognized the climate, biodiversity and food security co-benefits of ecosystem-based approaches. The environment ministers also recognized that "adaptation is a global challenge with implication at national, regional and local levels" and that climate impacts are context specific and felt locally. Thus while the G20 did not provide or endorse any specific definition of NbS, it did, at the ministerial level, and somewhat at the leaders' level, acknowledge key elements of NbS.

Two months later, on August 24-26, 2019 the G7 held its 2019 summit in Biarritz, France. Here the G7 leaders reiterated their commitment from the 2018 Charlevoix Summit, by "acknowledg[ing] the urgency to preserve marine and terrestrial ecosystems, including through nature-based solutions and the circular economy…" (G7 2019 Biarritz). Also notable was the G7's expression of support for the IUCN World Conservation Congress, then scheduled for June 2020, and the COP 15 of the UN Convention on Biological Diversity (UNCBD), then scheduled for October 2020.

Thus both the G7 and G20 have recognized that climate change is a global problem that requires multilevel governmental and nonstate actor engagement alike. With the energy and environment ministers' meeting at the G20, along with the joint environment, energy and oceans ministerial meeting held at the G7's 2018 Halifax ministerial meeting, there is evidence of an attempt to break down sectoral siloes, or at least to encourage collaboration among those government sectors that are most closely linked. Additionally, neither the G7 or the G20 defined or promoted a particular definition of NbS, but used it in the context of both conservation and green/natural infrastructure. Both institutions used NbS to promote a solution for climate change, while recognizing its other

environmental or biodiversity co-benefits, as well as the socioeconomic co-benefit of food security (in the case of the G20 environment ministers). Both institutions expressed support for the UNFCCC and for the UNCBD, while the G7 recognized the IUCN. This latter recognition, along with the G7's interest in developing standards and principles for natural infrastructure, suggests an opportunity for the G7 to consider and endorse the IUCN's definition, principles and standards on NbS. It could influence the G20 to do so too, as the G20 originally followed the G7's lead to include the NbS term.

In 2020 the G7 will be hosted at Camp David in the United States, and the G20 will be hosted in Riyadh, Saudi Arabia. G7 host, President Donald Trump, postponed the G7 summit until an undefined date due to the COVID-19 pandemic. At the time of writing, the U.S. had not released an agenda for its summit. The 2020 Riyadh Summit is scheduled for November, subject to the evolution of the pandemic. Saudi Arabia has kept NbS on its agenda, focusing on forest conservation, with an emphasis on afforestation. This suggests that the G20 will do more to advance NbS in 2020 than the G7. However, thus far, the G20's pre-summit meetings at both the leaders and ministerial levels have been preoccupied with responding to and recovering from the global health crisis. This should not, however, be a long-term diversionary shock, as the deterioration and destruction of nature, combined with emissions growth, is a key driving factor for the spread of such infectious diseases. Yet, the health shock, combined with a weak G7 leader in the U.S., along with Saudi Arabia's own efforts to water down multilateral climate negotiations and its commitment to the fossil fuel economy, strongly suggests that the G20 will struggle to make real progress on climate change at Riyadh. Despite this, some incremental advances for NbS may be made to support the overall picture of the global governance of climate change through NbS.

The next chapter delves into the scoping review of this paper, and discusses the key governance opportunities, barriers and challenges, and recommendations for overcoming these barriers, to improve the effectiveness of NbS governance and implementation.

4.0 Governance Opportunities, Challenges and Recommendations for Implementing Global Climate Change Goals through Nature-Based Solutions

With the institutionally-led definitions of NbS in 2015 and 2016 came a rise in scholarly studies on NbS (Mendes et al. 2019). Although systematic reviews have been conducted on the NbS literature (see for example Sarabi et al. 2019), the scoping review presented here uniquely focuses on NbS for climate change with a focus on global governance. This chapter presents the results of the scoping review.

4.1 The Scoping Review

To understand the strengths and limitations of "nature-based solutions," and to present the "lay of the land" on the academic research done on the global governance of NbS for climate change, a scoping review was conducted to provide a compact account of the opportunities, barriers and recommendations for effective NbS governance and implementation. A carefully selected set of peer-reviewed scholarly articles were reviewed for this information, that was collated into Appendices A and B and is reported in the subsequent sections to this Chapter (see section 2.3 Methodology for details). Section 4.2 on opportunities is categorized into a section on climate change mitigation and adaptation, societal co-benefits and governance (see Appendix A). Sections 4.3 on barriers and 4.4 on recommendations are both categorized into sections on jurisdictional, political and legal, financial, institutional, and stakeholder and partnership barriers/recommendations (see Appendix B). The opportunities highlighted provide a strong basis

for overcoming barriers and therefore for maximizing opportunities. Throughout, it discusses the global-local linkages that have been made within the literature, and ends with a discussion on these linkages within the context of global climate change governance and implementation.

While there are many lessons presented in the literature for improving the effectiveness of NbS, the overarching takeaway inferred from this review is that due to nature's inherent multifunctionality and cost-effectiveness, NbS can be highly effective for meeting global climate and societal goals *if* NbS implementation is guided by sound global principles and standards that allow for the use of a range of regionally or locally-appropriate assessment frameworks based on best practices and *if* multilevel and multi-actor collaborative governance is modelled. In this event, NbS can be a powerful approach with wide-reaching effects for emissions abatement and resilient and sustainable societies.

4.2. Opportunities of Nature-based Solutions for Climate Change and Societal Goals

Nature and nature-based solutions offer many opportunities for meeting global climate change goals, including from both a mitigation and adaptation or resiliency perspective. While nature-based solutions alone cannot stop emissions growth (for example, divestment from the fossil fuel and industrial agriculture sectors is needed etc.), neither can engineered or technical solutions alone stop emissions growth in the absence of nature. This paper is focused on nature's non-substitutable contribution to climate regulation, and resiliency and societal goals. As discussed in the previous chapter, a key comparative advantage and distinguishing feature of NbS, relative to technical- and market-based solutions, is its inherent provision of multiple ecosystem services, such as maintaining the balance of CO2 and oxygen in the atmosphere (see Appendix A). These services link the environment with human health and well-being, including services such as water and air purification;

heat reduction and cooling; recreation; cultural, spiritual and mental health benefits; containment of the spread of infectious diseases; food security and sovereignty; and more. NbS present governance-related benefits too. The governance and implementation of NbS directly supports the linkage between and progress towards multiple global goals, including the Paris Agreement, the SDGs and the UNCBD. This section reviews the opportunities of NbS discussed in the literature.

Climate Change Mitigation and Adaptation Opportunities

NbS was first conceptualized to meet global biodiversity and climate change goals, helping to link these two global regimes together. As discussed in Chapter Three, the initial focus of NbS was started by the World Bank and then led by the IUCN. A conservation focus was therefore the foundation for the conceptualization of NbS from a mitigation and carbon sequestration perspective. Natural processes regulate the balance of oxygen and CO2 in the atmosphere. Human species evolved from this balance created by plants and trees millions of years ago. While technology is needed for the shift from fossil fuel to renewable energy, and offers other benefits, there is no technological substitute for nature's role in balancing atmospheric CO2 for human survival. According to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (2019), nature can provide up to 37% of carbon mitigation. Nathalie Seddon et al. (2020) report that NbS can mitigate up to 5.8Gt CO2/year, while Helen Santiago Fink (2016) report that cities alone can provide up to 8.0 Gt of CO2e and 20% of carbon mitigation by 2050. These mitigation benefits are maximized only with careful planning and consideration of trade-offs. For example, natural forest regeneration stores 40 times more carbon than commercial, monocrop plantations, whose heavy reliance on chemicals have additional negative health implications (Seddon et al. 2020).

In order to avoid hitting the 2°C global average temperature target of the Paris Agreement, emissions mitigation is essential. However, given that the world heading toward a 4°C world and that there are no signs that governments and the biggest contributing sectors are raising their ambitions to stop their emissions growth, it is increasingly likely that global heating will go beyond the 1.5°C threshold (UN 2019; UNEP 2019). Facing this reality is essential, as doing so should motivate the policies and governance needed to live in such a world. This is especially important for developing countries and regions, and for low-income and marginalized groups within developed countries, for which there is a large research gap (Mendes et al. 2019).

This matters as NbS offers important advantages for vulnerability reduction and disaster risk resilience. Several studies highlight that nature is highly adept at reducing communities' exposure to so-called natural disasters and their multiple impacts, thereby increasing adaptive capacity (Seddon et al. 2020). For example, coastal cities and communities face increased risks from water-related hazards, including sea level rise and tidal waves that cause flooding. Protection against these extremes is more often provided by engineered solutions, such as sea walls. However, research shows that nature-based solutions provide better protection, including when used in conjunction with engineered solutions (Möller 2019). In other words, while a grey-green coastal defense strategy may be a good option, the literature suggests that engineered solutions alone are not enough. This is due to the fact that engineered solutions lack the flexibility of nature, such as wetlands; engineered solutions lack the ability to dynamically adjust to external environmental drivers, where natural landforms have this ability (Möller 2019). This knowledge can not only be applied to "ocean cities" or "island cities" but to any urban, peri-urban or rural area bordering water, many of which will likely need to contend with more frequent flooding as a consequence of climate change. The choice of mangroves or another species will depend on the geographical location of a given community.

Another water-related disaster is drought and water scarcity, which NbS can address too, such as through mangrove and grassland restoration, marine and forest protection, among others (Kalantari et al. 2018).

A major focus of the literature on NbS is on European cities, driven by the EU's regional policy on Nature-Based Solutions and Re-Naturing Cities (EC 2015; EC 2020a). This is largely due to the EU call for more research. Cities are an important area of study as the majority of the global population will reside in cities by 2030 (Kalantari et al. 2018). Yet most of this growth, 80%, is occurring in Africa and Asia (Kalantari et al. 2018), highlighting the need for more research on NbS for climate change in these regions (the majority of the literature on NbS for climate change focuses on European cities). However, the opportunities highlighted in the literature apply to cities on a global scale. Apart from the benefits mentioned above, another major benefit of nature in cities is its cooling effect and therefore resiliency from heatwaves (Bush and Doyon 2019). Cities contain vast amounts of concrete, which has a high emissions profile and which traps heat and is therefore a large contributor to the heat island effect (WEF 2019). This in turn increases the demand for air conditioners and cooling units, another source of emissions and thus global heating (UNEP 2019b). Adding and scaling up green roofs to existing concrete structures reduces energy consumption by 20%, and reduces structural façade temperatures by 4-8°C during the day and 1-2°C at night (Santiago Fink 2016). While alternative materials to concrete will need to be considered and used too, NbS in cities reduces the need for air conditioner use, and therefore also supports mitigation goals.

Societal Co-benefit Opportunities

Reducing the heat island effect and preparing densely populated areas for the increase in frequency and intensity of heatwaves is critical from a public health perspective, as extreme heat is a major cause of illness and death. Health is a common co-benefit cited in the NbS literature. This includes physical health, as well as mental health, happiness and overall well-being, including from a cultural, social and community perspective (Kabisch et al. 2016; Santiago Fink 2016; Artmann and Sartison 2018; Bush and Doyon 2019). These benefits are felt when in proximity to nature, and offer an added benefit over grey infrastructure which does not offer such health and well-being benefits (Artmann and Sartison 2018). This speaks to the benefits of NbS not only during disasters, but in the aftermath of such disasters and in times of stability too (Santiago Fink 2016; Artmann and Sartison 2018; Bush and Doyon 2019). In the aftermath of disaster, NbS offers socioeconomic resilience, with particular benefits for low-income and marginalized people. Martina Artman and Katharina Sartison (2018) found that the local production of small-scale urban and peri-urban agriculture as an NbS strongly supports food resilience in the wake of disasters, while contributing to food security during times of stability. This study also noted that urban agriculture reduces the need for pesticides and fertilizers. This supports climate-health goals too, as the overuse of these chemicals contributes to health-harming pollution and is a source of greenhouse gas emissions (Landrigan et al. 2018). Artmann and Sartison (2018) further found that urban agriculture as an NbS strongly supports social cohesion, especially for low-income people. This supports global mental health goals too.

Thus in the literature the primary social benefits highlighted are holistic health ones and social cohesion ones.

Governance Opportunities

In addition to climate change and social opportunities, the literature emphasizes two governance opportunities. The first is NbS' ability to encourage cooperation, coordination and collaboration among multiple actors (Seddon et al. 2020; Bush and Doyon 2019). The second is the cost-effectiveness of NbS relative to technical or engineered approaches (Santiago Fink 2016; Seddon et al. 2020).

On the first, the promotion of cooperation over competition is a great advantage as collaborative planning addresses uneven power relations (Bush and Doyon 2019). It is widely accepted in the reviewed literature that public input and stakeholder engagement brings benefits, particularly in terms of overcoming common governance barriers to the implementation of NbS (Ferreira et al. 2020). Stakeholder engagement and partnerships are discussed in further detail in sections 4.3 and 4.4.

On the second, economic advantages of NbS are derived from three revenue streams. The first is avoided economic losses in the event of disasters (Seddon et al. 2020). These avoided losses benefit those lowest on the socioeconomic ladder the most. The second are the cost savings due to the free socioeconomic services provided by nature. Ecosystem services have an estimated value of $125 trillion annually (Seddon et al. 2020). The third is that NbS is often found to be cheaper to implement compared to technical or engineered solutions (Santiago Fink 2016; Gopalakrishnan et al. 2019; Seddon et al. 2020).

While the climate, environment, social, economic and governance opportunities of NbS are many, several barriers stand in the way to maximizing these opportunities. The next section reviews some

of the common barriers and challenges to the implementation of NbS discussed in the literature, followed by section 4.4 on recommendations for overcoming these barriers.

4.3. Challenges of Nature-based Solutions for Climate Change and Societal Goals

The literature identifies governance challenges and barriers to implementing NbS for climate change. This section presents common barriers for NbS implementation the literature highlights (see Appendix B). These include jurisdictional barriers, including related political, policy and legal barriers; financial barriers; institutional barriers; and co-governance or multistakeholder/partnership barriers. The literature cautions that underlying these common barriers is an urgency to not lose sight of the need for "radical systemic change" (Seddon et al. 2020).

Jurisdictional, Political and Legal Barriers

The first barriers are jurisdictional, political and legal barriers. These are observed at all levels of government, among sectors and across national and international borders. Jurisdictional issues include siloed governance and land rights and claims, such as by Indigenous peoples. Siloed governance is the most commonly cited governance barrier in the reviewed literature. This has implications within and among countries, and from the local to the international levels. For example, at the municipal level there are divisions in departmental responsibilities, that are present at the national and state/provincial level too (Mendes et al. 2019; Seddon et al. 2020). These divisions prevent implementation or acknowledgement of shared responsibilities to the climate emergency. A department or agency mandated with responsibility for climate change may not communicate with other agencies mandated with responsibility for another issue that is relevant for climate policy, such as the energy or agriculture departments, and vice versa. Specialized departments tend to lack communication with each other (Seddon et al. 2020). Potential causes may include employees of a

given agency seeking to avoid over-stepping another agency. Conversely, employees may feel undermined if another agency takes action that falls under their own purview. There may also be a concern about duplication of efforts, that is often associated with inefficiency. But in the case of NbS for climate change, duplication may be appropriate as climate change and nature are cross-cutting and complex.

A less cited, but highly salient jurisdictional issue, was raised by Nathalie Seddon et al. (2020). Seddon et al. (2020) highlighted the trade-off of selecting land for an NbS that interferes with Indigenous land rights. Avoiding the incentivization of land grabs and land rights violations is a critical trade-off to avoid when implementing NbS (Seddon et al. 2020). Apart from the need to uphold human rights, recent research shows that land in the custodianship and management of Indigenous peoples is healthier and has better biodiversity outcomes (Schuster et al. 2019). This has implications for the quality of the ecosystem services the land can provide.

Another challenge, that flows from these jurisdictional issues, are political and legal. Here the literature refers to short election cycles and short terms of political leaders, who are pressured to evaluate policy options quickly (Mendes et al. 2019); unsupportive or conflicting incentives, regulations and legal frameworks (Seddon et al. 2020; Mendes et al. 2019; Artmann and Katharina 2018); and a general lack of governmental support was identified (Artmann and Katharina 2018).

Financial Barriers

Financial barriers are commonly cited. There is a general lack of funding and resources for implementing NbS projects, especially at the local level (Pederson Zari et al. 2019). For example, for municipalities, a significant challenge is insufficient allocation in the budget to implement and maintain green spaces in cities, particularly in tight financial periods (Kabisch et al. 2016). This includes during periods of recession or slow economic growth, or when there is an external diversionary shock. This could include health shocks, such as the COVID-19 global pandemic that shut down the global economy. These external shocks can make it more difficult for municipalities and other local governments to access financing from higher levels of government that may also be facing financial constraints. Here an important consideration is political preferences. For instance, the COVID-19 health shock presents an opportunity to transition support from brown to green sectors. However, while the world has injected trillions in economic stimulus in response to COVID-19, including the G20 countries that have pledged an estimated three times more than their fiscal stimulus response to the 2008-9 financial crisis (McKinsey and Company 2020), watchdogs have reported that most government spending is more brown than green (Carbon Brief 2020).

This trend speaks to the preference for investing in traditional sectors. The literature notes that there is a strong preference for investing in grey infrastructure, rather than in the green infrastructure that supports climate, biodiversity and equity outcomes (Kabisch et al. 2016). The over-valuation of traditional, grey sectors and infrastructure is a function of the under-valuation of nature and the natural environment. As such there is a pervasive failure to recognize expenditures on nature and ecosystem services, as well as on human and social capital, as assets (Seddon et al. 2020). The undervaluing of nature-based solutions results in a lack of its financing for implementation. Moreover, the traditional financing routes, as an alternative for financing beyond government

budgets, is an unsustainable debt-financing model (Seddon et al. 2019). Further, traditional lenders tend to lack an understanding of the project being implemented. They are highly motivated by short-term profits and therefore give less weight and less consideration to projects with medium- or longer-term benefits (Seddon et al. 2020).

Institutional Barriers

Another common barrier is institutional. These include institutional norms; path dependency; power-relations driving decisions; cultural contexts; cognitive factors, such as a lack of awareness of ecosystem services that are provided by NbS; discounting of climate risks; and a lack of perceived responsibility for action (Seddon et al. 2020). In general, institutional arrangements are unclear (Mendes et al. 2019). In practice, these institutional barriers were identified as the largest inhibitor for implementation of urban agriculture as an NbS (Artmann and Katharina 2018). Here there were unclear responsibilities at the municipal level, high costs and a general lack of government support.

Stakeholder and Partnership Barriers

A fourth barrier is multistakeholder engagement. Most articles reviewed argued that multistakeholder engagement, or collaborative governance, was needed for the effective implementation of NbS. However, this engagement comes with challenges. The challenges to multistakeholder engagement highlighted in the literature were primarily discussed in terms of on-the-ground NbS project implementation. However, the findings of these studies are applicable to the international level too. For example, the barrier of trust-building at the community level between stakeholders themselves and between the outside researcher and community members is evident in multi-actor negotiations at all levels of governance.

Trust-building is a key challenge for NbS implementation. This includes trust between stakeholder group members, and between stakeholders or local communities and outside researchers. Distrust between different members of the group may be present if the members represent different and/or conflicting sectors that are accustomed to working alone or only with like-minded colleagues (Meselhe et al. 2020). Outside researchers and practitioners may not fully understand or grasp what the on-the-ground implications of the proposed NbS are for the people living in that community as they will not be there to experience them (Meselhe et al. 2020). An additional consideration not highlighted in the literature is that community members may distrust outside researchers due to negative past experiences. This can include outsiders visiting the community conducting research, then leaving without ensuring that the promised benefits are delivered, which can be a particular problem for marginalized communities, such as Indigenous communities (Bull 2010).

Another challenge is the perception that multistakeholder initiatives can take too long, and that they therefore slow-down the implementation of projects (Ferreira et al. 2020). This is a particular concern in the context of climate change where little time is left to reverse course (IPCC 2019). Delays in reaching consensus are attributed to conflicts between members of the group, who represent different sectors and statuses in society and the community, and therefore have conflicting interests and priorities (Ferreira et al. 2020).

In a systematic review of stakeholder involvement in NbS implementation, Vera Ferreira et al. (2020) reported that stakeholders identified several barriers to NbS implementation. The top ones were a lack of knowledge and awareness of environmental problems, solutions and impact; lack of funding and financial constraints; lack of political support; and a lack of engagement due to low social cohesion. Stakeholders also identified trade-off risks of NbS, including environmental

injustice and unequal access, and other environmental trade-offs, such as attraction of unwanted/invasive species, allergies, and contamination. On the former barriers, lack of awareness is cross-cutting, and helps explain the lack of political and financial support from various levels of government, including budget allocations. Stakeholders additionally identified a need to understand the hierarchies of institutions and bureaucracies, dealing with conflicting points of views and interests, and feeling the involvement as time consuming and expensive for them were the top cited barriers to participation. Based on their findings, the authors also caution against the gap between theoretical expectations of challenges and actual challenges faced by participants in reality.

The identification of these barriers suggests that stakeholder involvement is valuable for identifying challenges, and ways to overcome them. Recommendations for overcoming these and the other jurisdictional and financial barriers are reviewed next.

4.4 Recommendations for Overcoming Barriers to Nature-based Solutions' Implementation

The literature on NbS for climate change offers several recommendations for overcoming these barriers (see Appendix A). These include promoting policy coherence and communication between otherwise siloed agencies and departments, respecting Indigenous land rights, institutional reform and flexibility, access to international financial resources, and multistakeholder engagement and partnerships.

Jurisdictional, Political and Legal Recommendations

A key recommendation for overcoming jurisdictional barriers is breaking down siloes. This requires "intra-communication" between departments and agencies (Mendes et al. 2019; Kabisch et al. 2016). This includes promotion of cross-border collaboration (Seddon et al. 2020). The recommendations

on bridging siloes are therefore applicable at all levels of governance. The promotion of coherence and communication also applies to the international level, where siloed governance is replicated and presents similar problems for NbS implementation. Nature, like climate change, does not adhere to artificial political boundaries and borders. Ecosystems are connected across borders and across jurisdictions, requiring the participation of local, national and regional governments, along with each of their different departments, agencies or ministries (Seddon et al. 2020), as well as international institutions and bodies. While including so many actors comes with the risk of being too time-consuming, the literature suggests that if all are focused on and can return to a clearly stated shared vision of human health and well-being through NbS for climate action, this can help to encourage collaboration over competition and contribute to overcoming other barriers to implementation (Lilli et al. 2020).

In the case of Indigenous jurisdiction, one proposed solution is to create a framework for NbS that takes these human rights into account, based on the Warsaw Framework for REDD+ (Seddon et al. 2020). A caution here is that some Indigenous nations believe REDD+ has weak safeguards against land grabs (Paquette 2016), raising questions about using this REDD+ framework as a base. Any such framework should be Indigenous-led. It is necessary for all countries at the international, national levels and subnational government level, to recognize Indigenous peoples' sovereignty and right to self-determination. As recommended in the IUCN's principles, NbS should be based on local, traditional and Indigenous knowledge (IUCN 2012). This includes including Indigenous actors in the co-design and implementation of NbS and engagement with traditional governance systems (Pederson Zari et al. 2019). It should also recognize that many Indigenous cultures have for millennia viewed nature as a living being with rights and that the idea of harmonious human-nature relationships is not a new idea.

Related to these jurisdictional issues are policy and legal ones. Here the literature identifies a need to overcome political and legal barriers by promoting policy coherence (Seddon et al. 2020). This includes by promoting legal requirements and coherence that influence policy and planning. There is also a need to be flexible in order to accommodate political shifts from election cycles (Mendes et al. 2019).

Financial Recommendations

In response to the difficulties accessing debt-free financing, to dealing with uninformed and profit-driven investors, along with the failure to recognize the value in expenditures on natural capital, and to restrictive budgets at the municipal level in particular, the literature offers several recommendations. A strong recommendation is to move away from traditional sources of financing to more innovative sources. This includes multilateral consortia of close partnerships (Seddon et al. 2020); exploration of non-traditional funding models, such as payment for ecosystem services, a model that incentivizes sound ecosystem management (Pederson Zari et al. 2019); collaboration and partnerships with non-profit organizations and volunteer community groups to raise funds (Ferreira et al. 2020); leveraging private and public funding to strengthen NbS, including strategic capacity building (Kabisch et al. 2019; Pederson Zari et al. 2019); and the creation of conditions, by local and trans-local governments, for new business and finance models that divest from dominant solutions (Kabisch et al. 2016). On this last recommendation, dominant solutions refer to investments for grey infrastructure efficiency "as the one and only focus" (Kabisch et al. 2016, 39). Nathalie Seddon et al. (2020), identified a need to test the effects of employing equity and risk sharing arrangements as an alternative to traditional financing, as well as a need to improve the measurement of human, social and natural capital as a way to convince investors and governments of the value of these

sustainability indicators. This is particularly challenging within the conventional economic system that does not adequately account for the monetary and non-monetary value of nature and its ecosystem services.

Lastly, Mabritt Pedersen Zari et al. (2019), focusing on Pacific ocean cities, recommended facilitating easier access to international funding. This is an important global-local link, as developed countries committed to mobilize US$100 billion per year by 2020 for climate financing at the 2009 Copenhagen Summit under the UNFCCC umbrella (Ballesteros 2010). This goal has been reiterated many times since, including within the G7 and G20 summits. But much more needs to be done to meet this goal (UN Climate Action Summit 2019). Moreover, since 2011 evidence has shown that even more climate financing is needed, especially to offset the substantial investments in high-emissions sectors. Topping up international climate financing mechanisms and accelerating funding deployment, that prioritizes NbS for meeting multiple global goals, is key.

Institutional Recommendations

NbS for climate change requires strong institutions with well-established planning structures, processes and instruments (Seddon et al. 2020). New forms of governance are needed, with transition management, strategic niche management and adaptive governance recommended due to their adaptive and holistic characteristics (Mendes et al 2019; Pederson Zari et al. 2019). Adaptive governance is an evolving approach for understanding multilevel governance that accounts for complex ecological problems, such as climate change, that intends to function in conditions of uncertainty and that takes a holistic over a linear perspective (Sharma-Wallace, Velarde and Wreford 2018). Rúben Mendes et al. (2019) recommend that co-design and participatory planning contributes to overcoming institutional blockages for NbS implementation, including through traditional

knowledge. Bottom-up coalitions of different actors for policy-making were identified as a key driver of success for implementing the specific NbS project of urban agriculture (Artmann and Katharina 2018).

Stakeholder and Partnership Recommendations

A final recommendation that receives strong emphasis in the literature is multistakeholder engagement and partnerships. This is relevant to this paper's approach which views effective governance as necessarily and importantly including but going beyond the state to include a multiplicity of actors in an interconnected and globalized world. The literature discusses stakeholder engagement primarily from a project implementation and thus local perspective. However, as with the other barriers and recommendations, the recommendations and findings here are relevant from a multilevel governance perspective. This helps explain the large focus on multi-actor engagement in the NbS-climate-governance literature.

Multiactor or stakeholder engagement and partnerships present both challenges and opportunities. The main opportunity is that engaging with the local community throughout the lifespan of an NbS project, from design to implementation and monitoring, has been found to help overcome the other discussed common legislative, financial, technical and social barriers encountered in NbS implementation (Lilli et al. 2020). Trust-building between group members of different social and professional backgrounds, and between local community members and outside researchers or practitioners, supports this. Different approaches are available to build trust. Ehab Meselhe et al. (2020) propose a community engagement approach. This approach ensures local residents are involved in NbS project planning, that have strong ties to the community, including an economic, historic and cultural connection, and who will be involved in every step of the design process. This

approach also focuses on validating these group members' local knowledge through knowledge-based validation assessments that confirm participants' observations. Alessandro Pagano et al. (2020) propose the Participatory System Dynamics Modelling approach. Both of these studies reported the respective approaches had positive outcomes for building trust among members, with the latter stating that the process helped to break down socioeconomic barriers.

On the flipside, a question that flows from stakeholders' seeking validation, is how to obtain stakeholder buy-in for NbS in communities that have not yet experienced the first-hand effects of climate change, or whose members are not fully convinced of the value of NbS for meeting the climate, environmental and social needs of the community. This could be termed an "out-of-sight, out-of-mind" phenomena. This calls for public education and awareness (Santiago Fink 2016). This includes within school curriculums. The literature also notes that just being around nature, or the presence of nature itself, encourages environmental awareness and action, especially when young people and children are exposed to it. It does so by fostering personal connections and experiences with nature (Santiago Fink 2016; Artmann and Katharina 2018). This can help invoke a sense of individual and collective responsibility for this public good.

Understanding what co-benefits of NbS people value in their communities supports the raising public awareness recommendation. In a systematic review of academic articles on NbS with links to stakeholder involvement, Vera Ferreira et al. (2020) reported that the environmental co-benefits stakeholders cited most were climate regulation and air quality. These were followed by biodiversity and wildlife benefits, shade, and water runoff mitigation. The most frequently perceived social benefit of NbS was proximity to nature, with physical and mental health a close second, followed by recreation and exercise, and sociocultural benefits. The economic benefits cited included food

security, an increase in property value, and wood provision. In all, stakeholders viewed engagement in NbS as having multiple opportunities. This included promoting social cohesion, connecting people with nature, encouraging a sense of belonging, raising environmental awareness, and establishing long-term partnerships to obtain funding, among others.

Building from Meselhe et al.'s (2020) work to include partners with a historical connection to the community where the NbS is being implemented, is the need for inclusivity in NbS decision making. Inclusivity is important in order to avoid contributing to and exacerbating existing unequal power structures and inequities. The most marginalized and silent people and groups need to be part of the design and implementation of NbS (Pederson Zari et al. 2019). Women are a critical group, particularly in consideration of norms around traditional gender roles and in recognition of Indigenous women as traditional knowledge keepers, such as in Pacific island nations and around the world (Pederson Zari et al. 2019). The inclusion of these groups can support the needed community buy-in, and trust-building too. European cities have also begun incorporating citizen participation and collaboration between planners and developers precisely to overcome these types of challenges (Ferreira et al. 2020). These examples suggest that the benefits of collaboration can outweigh concerns over slow decision making.

Supporting the overcoming of conflicts among stakeholders and partners is the recommendation to have a clear vision at the outset of a given NbS project (Lilli et al. 2020). This helps participants resolve conflicts by redirecting their attention away from conflicting views, differences and mandates, and toward a shared common purpose that benefits everyone. Having a clear vision also contributes to operating in conditions of uncertainty. This has particular salience in the context of global climate change governance where a degree of uncertainty is omnipresent. Acknowledging

uncertainty is an important factor in breaking through bottlenecks in NbS for climate change. To do so, Iris Möller (2019) recommends that decision makers start by asking what *is* certain within the uncertain, and then ask what the implications are of what is certain for decision making. In answering these questions, local knowledge is emphasized as offering a way forward. Emmanuelle Cohen-Shacham et al. (2019) recommend that uncertainty be added to the IUCN's eight principles for NbS implementation.

These examples show that, while conflicts among group members cannot be easily overcome, that a multistakeholder approach to NbS implementation should not be avoided due to perceptions or fears over potential disagreements or bottlenecks. Some conflict is likely unavoidable. Yet a poor outcome should not be assumed for every conflict; conflict can oftentimes result in better, more sustainable outcomes if addressed wisely and if all members share a common vision. Stakeholder engagement and public input is therefore essential to NbS' success and effective governance, which is being increasingly accepted by policymakers (Ferreira et al. 2020).

4.5 Discussion: "Think Globally, Act Locally" for Effective Implementation of Nature-based Solutions[6]

The opportunities, barriers and recommended solutions reviewed above centre on an overarching theme of effectiveness of NbS implementation for climate goals, taking account of the global to local, or multilevel/polycentric, linkages (Lafortezza et al. 2018). This focus is in recognition of the global and local drivers that contribute to climate change and environmental degradation (Pederson

[6] Wendling, Laura A., Aapo Huovila, Malin zu Castell-Rüdenhausen, Mari Hukkalainen, and Miimu Airaksinen. 2018. "Benchmarking Nature-Based Solution And Smart City Assessment Schemes Against The Sustainable Development Goal Indicator Framework". *Frontiers In Environmental Science* 6. doi:10.3389/fenvs.2018.00069.

Zari et al 2019) and the recognition that the global climate change governance landscape continues to shift from a state-centric regime to a more complex networked and multilevel regime where nonstate and substate actors are increasingly influential in the global governance of climate change (Abbott 2012; Bäckstrand et al. 2017; Boran 2019). This trend calls for a "think globally, act locally" perspective when considering the effectiveness of NbS for climate change (Wendling et al. 2018, citing Geddes 1915).

The UN's SDGs offer a benchmark against which to apply such a perspective. Laura Wendling et al. (2018) compared three NbS assessment frameworks, each with a focus on NbS in cities, against the SDG 11 indicators on sustainable cities and communities. The SDG 11 indicators address the three overarching sustainability themes of the SDGs of the environment, society and economy. The three selected frameworks were the Mapping and Assessment of Ecosystems (MAES) framework, the EKLIPSE framework, and the CITYkeys framework for smart cities (Wendling et al. 2018). The authors found that none of the three frameworks were fully synergistic with the SDG 11 indicators. This surprisingly included the SDG 11.5 indicator of disaster preparedness, a central goal of NbS for climate change adaptation and resiliency. This finding was partially attributed to the fact that the three selected assessments "are European assessment frameworks corresponding to European needs whilst the SDG targets and related indicators, although applicable globally, were formulated with significant consideration of developing countries' urgent needs" (p. 14).

This observation raises questions about Eurocentricity in NbS governance and implementation. Most of the NbS literature focuses on European cities, namely in the three G7 countries of the United Kingdom, Germany and Italy, as well as in Spain, Portugal, Sweden and the Netherlands (Mendes et al. 2020). Outside of the EU, the U.S. and China have the most publications on NbS.

Thus developing countries within the regions of Africa, Asia and Latin America are underrepresented and under-researched in the NbS literature. This matters for assessing the effectiveness of NbS as the literature and corresponding NbS assessment frameworks, while emphasizing inclusivity, fail to take into account developing countries' circumstances. The NbS literature emphasizes that the majority of the global population will be concentrated in urban areas, and based on this focuses its geographical analysis on European cities. However, 80% of this urban growth is taking place in African and Asian cities, not in Europe (Kalantari 2018). While the opportunities and barriers presented in this paper are general and therefore can be considered on a global scale, they lack recognition of distinctive regional factors beyond the European context.

This, combined with the need for multilevel and multi-actor collaborative governance and for adaptative and flexible governance, suggest that multiple NbS assessment frameworks that can account for regional differences is likely optimal. It may not be feasible or realistic to have one universal framework for assessing the effectiveness of NbS, as "simple standardized metrics of NbS effectiveness that can comprehensively capture complex social-ecological dimensions is unlikely to be found" (Seddon et al. 2020, 7). Nathalie Seddon et al. (2020) recommend "a suite of context-specific metrics to enhance understanding of effectiveness at the local level" (p.7). This approach could encourage the uptake of NbS and thereby support the advancement of NbS to the scale required to meet global climate and socioeconomic goals. Here a global set of principles and standards to guide the development of context-specific frameworks can help bridge the global and local links. Emmanuelle Cohen-Shacham et al. (2019) argue that for NbS to be effective there needs to be "clear and coordinated principles, on which evidence-based standards and guidelines for practitioners and decision-makers can be developed" (p. 21). They defined effectiveness as the ability of NbS to be implemented at the scale required to reverse severe ecosystem degradation.

From a sustainability perspective, Laura Wendling et al. (2018) included the concept of intergenerational equity in their definition of effectiveness. Global principles and standards are aligned with the recommendation on stakeholders and partnerships that a clear shared vision facilitates agreement and conflict resolution, and therefore progress on NbS implementation.

An additional consideration regarding stakeholders and partnerships is on innovation, which Diana Dushkova and Dagmar Haase (2020) argue is a distinguishing feature of NbS. They argue the conceptualization of NbS supports the mainstreaming of inclusivity and engagement in decision-making among different actors. This includes in regard to multicultural societies, environmental justice and in behaviours, with the former two particularly salient for the developing world, as well as for low-income and marginalized communities in the developed world. However, in a summary of NbS assessment frameworks, Alessandro Pagano et al. (2019) observe that a common, although not universal, limitation is poor accounting of stakeholder involvement, along with limits for proving the multidimensional effectiveness of NbS. Christopher Raymond et al. (2017) agree, and argue that existing frameworks for assessing NbS' effectiveness do not address the complexity of NbS well enough. Alessandro Pagano et al. (2019) propose a Participatory System Dynamics Modelling approach, which includes both a quantitative and qualitative component. This proposal complements those put forward by Meselhe et al. (2020) for a community engagement approach and the findings by Lilli et al. (2020) that collaboration supports overcoming legislative, financial and other barriers. As with the suggestion that various assessment frameworks is optimal, the successes reported by these distinct stakeholder engagement approaches similarly suggests that an optimal outcome can be achieved through a range of participatory approaches. Thus the move towards devising global principles and standards should not be interpreted as promoting a universal homogeneous or "one-size-fits-all" NbS implementation and assessment framework, but rather for

promoting a shared global vision to guide a diversity of assessment frameworks that take account of local realities.

The emphasis on multilevel governance in the literature, and in particular on the need for state and nonstate actor participation, supports the trend to a more inclusive global climate change governance landscape. Whereas traditional perspectives of global governance viewed the state as the primary actor, the advent of the Anthropocene, where humans have an unprecedented impact on their environment, implicates every level of government and segment of society. A criticism of the 1992 UNFCCC and of the 1997 Kyoto Protocol was that only the developed, industrialized countries were bound to reduce their emissions. The 2009 Copenhagen Accord failed to expand responsibility to emerging economies, such as the BRIC group of Brazil, Russia, India and China. Today, although it succeeded in including binding all countries to reduce their emissions regardless of economic status, the 2015 Paris Agreement has received criticism for including only states in its emissions accounting system. This criticism is founded in observations that nonstate actors have high emissions profiles. For example, just 100 multinational corporations are responsible for over 70% of global emissions (Climate Accountability Institute 2017) and cities account for 75% of global emissions and 60-80% of total energy consumption (Wendling et al. 2018). The global governance of climate change therefore requires a holistic whole-of-society approach. The suggestion for multiple metrics and frameworks for assessing the effectiveness of NbS is aligned with the characteristics of nature itself as interconnected, multifunctional, flexible, adaptable and dynamic to external shocks and circumstances.

5.0 Conclusion

This paper has reviewed the history and evolution of the conceptualization of NbS in global climate change governance, from 2008 to the present. It reviewed key debates in the literature regarding the definitions of NbS put forward by the EU and IUCN. Two central debates are the "grey-green infrastructure debate" and the "greenwashing debate." Both raise questions over the usefulness of NbS as a new concept, how NbS differentiates itself from existing nature-based approaches, and what should count as an NbS if such a concept is accepted. This paper showed that the NbS concept is gaining within global governance institutions and is becoming mainstream in national and international policies (Dushkova and Haase 2020). This is in part demonstrated by NbS' appearance on the G7 and G20 agendas in 2018 and 2019, respectively.

This paper presented the results of a scoping review, with a focus on the NbS governance opportunities, barriers and recommendations for overcoming these barriers. Although the information presented is not exhaustive, this paper painted a picture of some critical elements highlighted in the literature for maximizing the multifunctional opportunities offered by NbS and that support the realization of global climate and socioeconomic goals. Although meeting the 1.5°C target of the Paris Agreement appears increasingly elusive due to business continuing as usual and a lack of ambition, it is not too late to avoid the worst impacts of a 2°C world (IPCC 2019). Yet the realities of a 1.5°C world need to be accepted and prepared for, calling for strong and urgent action for adaptation and resilience through nature alongside efforts to halt the growth in global emissions through other types of solutions.

This paper acknowledges that the idea of meeting multiple goals through nature is not new, and that many cultures around the world, including many Indigenous cultures, have been promoting the

protection of nature for millennia and hold worldviews that are holistic. Keeping this in mind, this paper views the term nature-based solutions as a useful umbrella term in that it uses language that equates nature with "technical-based solutions" and "market-based solutions" that have pride of place as tools for meeting global climate change and societal goals. However, these latter catch-all terms exclude the environment and nature, and as such are limited in addressing the complexity of climate change.

In light of the fact that nature itself is interconnected and holistic, NbS as an umbrella term helps create a space for more creative and innovative thinking. This matters, as a paradigm shift is needed (Santiago Fink 2016; Kabisch et al. 2016; Seddon et al. 2020). Within the reviewed NbS-climate literature, there are calls for "radical systemic change" and governance "shifts," against the backdrop of critiques of the demands of the growth-based economy and the upholding of a linear status quo as the highest barrier to meeting the call for transformative change (Kabisch et al. 2016; Bush et al. 2019; Seddon et al. 2020). This paper agrees that the highest opportunity to meeting global climate and social goals is the re-imagining of the current linear-based model to a holistic-based model that recognizes humans as part of nature rather than as separate from nature. With this systemic consideration in mind, the key takeaway of this scoping review is that due to nature's inherent multifunctionality and cost-effectiveness NbS can be highly effective for meeting global climate and societal goals if NbS implementation is guided by sound global principles and standards that allow for the use of a range of regionally or locally-appropriate assessment frameworks based on best practices and if multilevel and multi-actor collaborative governance is modelled. In this event, NbS can be a powerful approach with wide-reaching effects for emissions abatement and resilient and sustainable societies.

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Appendix A: Opportunities for the Implementation of NbS for Climate Change

Climate mitigation	Climate adaptation	Socioeconomic co-benefits	Governance
0.4-5.8Gt CO2/yr mitigated (Seddon et al. 2019) Cities can provide up to 8.0 Gt CO2e by 2050 and 20% of carbon mitigation (Fink 2016).	Reduces vulnerability, exposure and sensitivity (Seddon et al. 2019; Pagano et al. 2019)	Provides economic benefits through avoided losses in terms of disasters (Seddon et al. 2019)	Enables active cooperation and coordination between multiple stakeholders (Seddon et al. 2019) Collaborative planning addresses uneven power relations and encourages (requires openness to diverse and fluid discourse communities to co-learn and problem-solve to achieve stated desires (Bush et al. 2019) Understanding stakeholders' perceptions of, and preferences for green spaces and engaging them in the planning process can potentially bring benefits to residents and urban planners (Ferreira et al. 2020).
Natural forest regeneration stores 40X more carbon than commercial plantations (Seddon et al.)	Increases adaptive capacity (Seddon et al. 2019)	Provides wide range of ecosystem services, with particular benefits for the most vulnerable (Seddon et al. 2019)	Low-cost solutions, including at the local scale (Seddon et al. 2019; Fink 2016; Lafortezza et al. 2017), whereas grey solutions are capital intensive (Pagano et al. 2019).

	Protects against multiple disaster impacts (Seddon et al. 2019)	Ecosystem services provide economic benefits of $125 trillion annually (Seddon et al. 2019)	Protects against multiple impacts (Seddon et al. 2019)
	Enhances urban resilience to sudden change and disruptions from natural disasters, such as by mitigating climate impacts, including heatwaves and storms, with green infrastructure usually inherently more resilient than large, centralized grey infrastructure (Bush et al. 2019) On heatwaves, greener cities are cooler. For example, green roofs reduce energy consumption by 20%, and reduce structural façade temperatures by 1-2°C at night and 4-8°C during the day, reducing the need for air conditioners (Fink 2016). Urban agriculture supports food resilience after natural disasters (Artman 2018).	Urban agriculture as an NbS reduces environmental impact by providing a bundle of ecosystem services, including biodiversity, cultural benefits, nutritional value by reducing the need for pesticides and fertilizers, the promotion of social interaction and cohesion, contributes to mental and physical health, improves environmental awareness, promotes food security and social cohesion for low-income earners, supports food resilience after natural disasters (Artman 2018). NbS in cities has added value related to grey infrastructure by raising environmental awareness and action; mental health benefits, including reduced stress from a physiological perspective and a restorative perspective, including in the work environment (Fink 2016). NbS in urban areas is good for ecosystem services, especially cultural, social and community wellbeing and benefits during times of stability (Bush et al. 2019). This includes rich biodiversity services (Fink 2016)	Builds a conceptual bridge between ecosystem services, day-to-day social concerns and governance (Mendes et al. 2019).
	For coastal protection, unlike engineered approaches, natural landforms dynamically adjust to external drivers (such as wave and tidal energy). Natural landforms can therefore potentially persist where engineered structures cannot (Möller 2019).	Health benefits: Increased happiness and wellbeing, and increased physical health benefits, such as reduced rates of respiratory diseases and obesity (Kabisch et al. 2016).	

	Overtopping risk is reduced where there are wetlands in the presence of other natural defenses, such as dunes, or engineered defenses, such as sea walls (Möller 2019).	Mental, wellbeing and physical health benefits (Fink 2016; Artman 2018; Bush et al 2019).	
		The strength of the NbS concept lies in its integrated perspective in addressing societal challenges (Lafortezza et al. 2017)	

Appendix B: Governance Challenges for the Implementation of NbS for Climate Change

Governance Issue	Challenge	Proposed Solution
Financing	Difficult to access and obtain financing, with many investments financed by debt, with traditional lenders lacking an understanding of the project, and with short-term profits prioritized (Seddon et al. 2019)	Multilateral consortia of close partnerships as an alternative to traditional financing (Seddon et al. 2020). Work is needed to test the effects of employing equity, risk-sharing arrangements rather than debt finance for NbS (Seddon et al. 2020). Collaboration of nonprofit organizations and voluntary community groups and partnerships can raise funds for the development of those solutions (Ferreira et al. 2020).
	Failure to recognize expenditures on human, social and natural capital as assets (Seddon et al. 2019)	A need to greatly improve the measurement of human, social and natural capital (Seddon et al. 2019)
	A significant challenge for city administrations is the allocation of a sufficient budget for implementing and maintaining green space projects in cities' tight financial periods (Kabisch et al. 2016).	Local and trans-local governments should create conditions for new business and finance models by divesting from dominant solutions, i.e. investments in optimizing efficiency of grey infrastructure as the one and only focus, and by leveraging private and public funding in strengthening NbS (Kabisch et al. 2016).
	Lack of funding and resources (Zari et al. 2019)	Exploration of non-traditional funding models, such as payment for ecosystem services (Pederson Zari et al. 2019) Utilization of international aid funding (Pederson Zari et al. 2019) Strategic building of capacity and relationships with the private sector (Pederson Zari et al. 2019)

Jurisdiction	Crossing jurisdictional boundaries requires joint decision making across different local, regional or even national governments and different ministries (Seddon et al. 2019) Where jurisdictional and biophysical boundaries are inconsistent trade-offs or jurisdictional conflicts may persist (Bush et al. 2019)	Requires co-management or multilevel governance approaches (Bush et al. 2019).
	Lack of policy coherence: One agency sees an issue, i.e. adaptation, as the responsibility of another; trade-offs leading to conflicts (Seddon et al. 2019) Sectoral silos (Kabisch et al. 2016).	Promote policy coherence (Seddon et al. 2019) Remove administrative barriers and/or create incentives to encourage collaborative governance between cities, businesses and citizen organizations, or reflexive governance (Kabisch et al. 2016).
	At the municipal level, division of departmental responsibilities and related communication is a barrier (Mendes et al. 2019). Improved urban institutional coordination is needed at the government level, within sector agencies and with local government, climate change offices and disaster management offices (Zari et al. 2019).	Attention must be given to 'intra-communication' to enable different departments to build NbS together (Mendes et al. 2019). Communicating the benefits of NbS across sectors and departments for bridging siloes (Kabisch et al. 2016)
	Land tenure: for Pacific ocean cities complexities from customary land and dual land tenure mechanisms, as well as internal migrants who lack customary land rights in informal settlements, are present (Zari et al. 2019).	Complex land ownership structures, transfer of ownership or right to use land and water and traditional understanding of human-nature relationships must be clearly understood, recorded and mapped; investigation of methods of working with these structures differently or changing them if they are actively preventing NbS (Zari et al. 2019).
Politics, Policy and Legal	Unsupportive or conflicting incentives and regulations (Seddon et al. 2019) At the municipal level, the legal framework is a barrier (Mendes et al. 2019)	Promote the study of legal requirements that are adequate to influence policy and planning (Mendes et al. 2019)
	Short election cycles with fast evaluation of the political options (Mendes et al. 2019)	At the municipal level green policies need to be institutionally and politically flexible to accommodate the natural political shifts resulting from elections (Mendes et al. 2019)

	Discontinuity and disconnect between short-term actions and long-term plans and goals (Kabisch et al. 2016)	
Institutional	Institutional norms: path dependency; power-relations driving decisions; cultural contexts; cognitive factors such as lack of awareness of ecosystem services provided by NbS, lack of perceived responsibility for action, discounting of climate risks (Seddon et al. 2019)	Requires strong institutions and well-established planning structures, processes and instruments to ensure benefits across landscapes and seascapes (Seddon et al. 2019)
	Institutional arrangements are not clear and need to be explored (Mendes et al 2019).	Newer forms of governance, such as transition management or strategic niche management; requires adaptive, holistic planning approach (Mendes et al. 2019) Co-design and participatory planning initiatives may contribute to overcoming frequent institutional blockages for NbS implementation, including tradition knowledge (Mendes et al. 2019)
	A challenge of participatory approaches is a lack of trust, such as in a community-based approach (Meselhe 2020).	This can be addressed through knowledge-based model performance assessments that validate the community members' observations and lived experiences (Meselhe 2020).
	Most constraints for urban agriculture as an NbS are institutional, including lack of government support; unclear responsibilities at the municipal level; limited resources, including costs (Artman 2018).	For urban agriculture as an NbS need broad coalitions of different actors; emphasis on multidimensional benefits to garner authorities support (bottom-up policy making); policy and legal regulations to support UPA; create funding and employment opportunities (Artman 2018).
Systemic	NbS may be a distraction from the urgent need to rapidly decarbonize (Seddon et al. 2019) Demands of growth-based economy that favours extractive land-uses and short-term profits (Seddon et al. 2019)	Need radical systemic change (Seddon et al. 2019)

	Paradigm of growth (Kabisch et al. 2016)	
	Reproduction of the status quo prevents transformative potential of resilience initiatives and neglects the implications for social justice and equity (Bush et al. 2019)	Governance also needs to shift towards more anticipatory and proactive approaches [Coaffee et al., 2018], and connecting different actors and sectors in order to focus on "mainstreaming a resilience approach in all the city-level decision making" (Bush et al. 2019)
Measuring Effectiveness	Lack of indicators for measuring the effectiveness of NbS for climate change mitigation and adaptation (Mendes et al. 2019)	Four important indicators that should be considered in the assessment of NbS: 1. Integrated environmental performance; 2. Human health and well-being; 3. Citizen involvement; and 4. Transferability (Kabisch et al. 2016)
	Monitoring and evaluation of projects by policy makers and land managers is often not well-resourced. As a result, monitoring data may not be collected, or there may be a reliance on ad hoc collection of citizen-science generated data, as well as challenges in understanding and interpreting data related to biodiversity and ecological systems and functions (Bush et al. 2019) Sociodemographic and socioeconomic data need to be included in an assessment (Kabisch et al. 2016)	
	Making decisions in the face of uncertainties (Möller 2019)	Ask what is certain within the uncertain and then what are the implications of what is certain for decision-making? (Möller 2019) Local knowledge may offer a way forward for estimating worst-case scenarios, in the context of coastal protection (Möller 2019).
Stakeholders/Partnerships	Promoting inclusive, active participation and community-led action and community-based solutions is vital for advancing implementation in ocean cities (Zari et al. 2019).	There should be early engagement with community leaders (such as landowners, chiefs, the marginalized and more silent, women, youth etc.), with entry points for engagement including government development processes, public consultation, traditional governance systems, the activities of civil society and faith-based

		organizations and groups for women, men, youth and others (Zari et al. 2019).
	The involvement of locals is still rarely adopted, mainly due to the general perception that multistakeholder initiatives slow down urban planning and policy development processes due to a lack of consensus and different sectoral interests (Ferreira et al. 2020).	Stakeholders' perceptions on the co-benefits, risks, design preferences, challenges and opportunities can provide valuable information for the effective implementation of NbS (Ferreira et al. 2020). Case studies with stakeholder involvement show that it helps overcome existing social, political, legal and institutional barriers (Pagano et al. 2019) Using proven participatory models helps build trust among members (Pagano et al. 2019; Meselhe et al. 2019).