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# NATURE-BASED SOLUTIONS: A REVIEW OF THE CONCEPT, ADVANTAGES, AND FACTORS DETERMINING ITS POTENTIAL SUCCESS IN THE SOUTH AFRICAN CONTEXT

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# PREFACE AND ACKNOWLEDGEMENTS

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# EXECUTIVE SUMMARY

## Introduction

Over the past decade, the concept of nature-based solutions (NbS) has gained prominence in policy, research and business efforts to advance sustainable development aspirations. The concept emerged rapidly as a means to respond to the challenges of climate change and biodiversity loss, but does not yet have unanimous support, with a number of governments, bodies and organisations unconvinced or dismissive of the NbS concept and its utility. This is due to uncertainty about its effectiveness, and controversies over its potential misuse to avoid making real gains required to address environmental issues. In addition, support and uptake in the global south has been relatively poor, due to concerns about its alignment with development objectives as well as the greater challenges associated with its implementation in these regions. The aims of the study were:

- to provide clarity on the concept, particularly in the context of addressing climate change;
- to interrogate its cost-effectiveness compared with "conventional" approaches;
- to understand what might limit its uptake and application in South Africa; and
- to provide guidance on best practice for South Africa.

## Conceptual overview

Numerous authors have offered definitions of NbS, with the most commonly-used being those of the IUCN and the European Commission. In 2022, the United Nations Environment Assembly defined NbS as "*Actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services and resilience and biodiversity benefits.*" This definition has now been widely accepted, including by the South African Government.

The following six criteria need to be met for measures to qualify as NbS:

- alignment with natural ecosystem processes;
- benefitting biodiversity;
- adaptability;
- being locally appropriate;
- being multifunctional; and
- enhancing human wellbeing.

The concept of NbS aims to explicitly link positive outcomes for society (i.e., 'solutions') with a view of 'nature' as being helpful in achieving these aims. The word 'solutions' is not meant to convey a guarantee of success, or encourage burden-shifting, but rather that these approaches facilitate *positive* outcomes to societal challenges. While 'approaches' may have been better choice, it is unlikely that efforts to rebrand the concept will be successful now that the NbS term is entrenched and would hinder progress on the development and implementation of NbS. While NbS have a critical role to play in addressing the climate and biodiversity crises, they should be framed as a complement to other solutions, particularly reductions in fossil fuel emissions.

NbS offers alternatives to conventional measures to address a wide range of societal challenges. It is important to recognise that these could be presented as sectoral challenges (e.g. water security) or climate-related challenges (e.g. adaptation), and that addressing the former also constitute means for addressing the latter. Understanding this can be helpful in alleviating some of the confusion around NbS and related terminology. Clear definitions are important in framing national policies.

Societal challenges are conventionally addressed using "grey" engineering measures ("grey infrastructure"). However, over time, there has been a tendency to develop more environmentally friendly ("green") measures ("green engineering"), and more recently, to take more advantage of ecosystem services ("nature-based solutions"), often in combination with more conventional measures (Figure I). Initially, the latter focused on maintaining the condition and capacity of existing natural ecosystems ("ecological infrastructure"), but it also became apparent that one could construct ecosystems to perform services ("engineered ecosystems") and that it is also possible to change the way that cultivated ecosystems are managed in order to restore some of their original landscape services while still generating provisioning services ("sustainable cultivated systems").

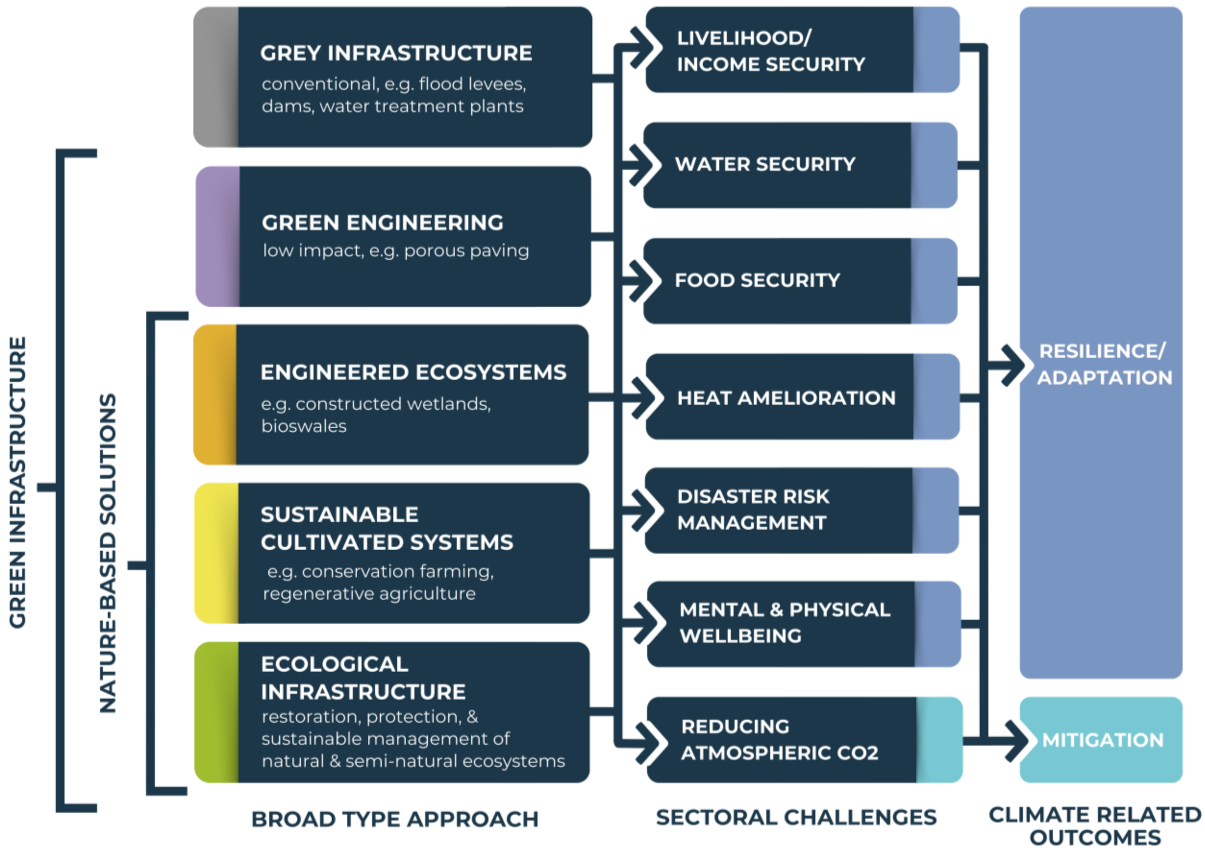


Figure I. How green and nature-based solutions fit into the continuum of natural to engineering approaches used to address societal challenges, and the associated sectoral and climate-related outcomes. Source: Authors.

There is some overlap between these terms, and some terms that encompass a range of measures. For example constructed ecosystems can be included under the term "green engineering", and green infrastructure encompasses all measures that have positive environment impacts relative to the conventional grey engineering solutions. In general, confusions around terminology arise due to a plethora of related terms that has resulted from related concepts emerging in different disciplines and in different parts of the world, including broadening the meaning of words from that in their original discipline (notably “nature” and “ecosystem”).

NbS interventions can be characterised based on (a) the type of action, (b) the challenges addressed and (c) the type of landscape in which they are implemented. For example:

- Natural catchment areas can be protected to maintain hydrological services that help to maintain the yield and lifespan of constructed reservoirs, contributing to water security, climate change adaptation and mitigation.
- Conservation farming practices can be implemented to improve the capacity of cultivated systems to retain soil and moisture, again helping to maintain the longevity of built infrastructure downstream through reduced sedimentation, so contributing to water security as well as food security.
- In urban areas, artificial wetlands can be constructed to further improve the quality of treated wastewater, to better maintain the quality of downstream ecosystems and the ecosystem services that they supply, such as recreation and fisheries.

### Cost-effectiveness of NbS

NbS are widely claimed to be both economically viable and cost-effective ways of solving societal challenges compared to other more conventional engineering interventions used alone. The literature suggests that the potential benefits of NbS for climate resilience and halting biodiversity loss are significant, with a high return on investment. However, concerns remain over the cost-effectiveness of NbS compared to engineered solutions and this is a key barrier to implementation at scale. Most studies have focused on economic viability (benefits exceed costs), rather than cost-effectiveness, which compares the costs with alternative approaches to delivering a specified outcome. Both are challenging because of the complexity of estimating costs, estimating changes in multiple ecosystem services that vary over time and the uncertainties of climate change effects on these. Studies have to rely heavily on modelling and projection. Nevertheless, with the significant improvements in these techniques over the last decade, the many feasibility studies that have been carried out generally provide a strong case for NbS. Results will always be context-specific, however.

### Barriers and challenges to adopting and implementing NbS

Uncertainties persist with regard to when, where, how and for whom NbS are effective. As a result, practical knowledge regarding NbS remains fragmented. There are numerous barriers and challenges that have limited the successful implementation and uptake of NbS worldwide. There is a rising criticism of NbS due to activities that are carried out in the name of NbS without meeting its criteria or standards and resulting in negative impacts on biodiversity and ecosystem services. The main issue in this regard is relates to the inappropriate planting of trees (e.g. replacing natural forest with exotic plantation, or planting trees in habitats where they would not naturally occur) as a means of climate change mitigation. Lack of comprehensive monitoring and evaluation has led to knowledge gaps and uncertainty around NbS. Social challenges include issues around inclusivity, collaboration and engagement with local communities and indigenous people which has led to social justice concerns, impacts on cultural practices and even displacement and marginalization of local people when poorly considered. Because the implementation of NbS often requires high upfront costs at scale, financial barriers are one of the key challenges, necessitating innovative financing solutions and/or external funding. Substantial opportunities exist for funding from the Adaptation Fund, the Green Climate Fund and the Global Biodiversity Framework Fund. Political support for NbS has been low due to uncertainty about its cost-effectiveness, and concerns about the negative social impacts of imposing changes in land use and management. As a result, some of the institutional and policy reforms needed to ensure the success of NbS have not been addressed. However, political support is likely to increase as nature-related risks and opportunities become better understood.

### NbS best practices

South Africa has extensive experience in the development and implementation of NbS, particularly actions relating to the restoration and management of natural and semi-natural ecosystems. Its programmes in this regard have predated the concept of NbS, and there has therefore been some lag in the recognition of existing activities as part of this newer paradigm. Most of this experience has been through its natural resource management (NRM) efforts under the Expanded Public Works Programs (EPWP), involving the restoration and management of ecosystems and landscapes, sustainable harvesting and the management of fire risk. It has also made significant policy advancements on NbS practices in urban areas. Most of these efforts have addressed sectoral challenges and/or adaptation. There is less experience in mitigation, and this is mainly in the private sector.

South Africa has already developed best practice guidelines for EbA, which would also apply well to the broader concept of NbS. NbS guidelines and practices have also been developed and negotiated in the UNFCCC and CBD forums, and these are easily transferable to the local context. These include the extensive body of information developed during the development of REDD+ policies under the UNFCCC, the Nairobi Work Program technical work on EbA, IUCN's Global Standard for NbS (2020) and the proposed governance structure, and NbS guidelines complementary to the IUCN Global Standard, with the aim to have the guidelines be adopted to the UNFCCC.

### Conclusions and recommendations

Over the past decade there has been a rapid rise in the prominence of the concept of NbS, which has strong international policy and business support particularly in developed countries. Because of the numerous related terms that have emerged in different parts of the world over the last few decades, the concept of NbS is often confused. EbA encompasses actions to restore or secure ecosystem services that help to address sectoral challenges, climate change adaptation and/or climate change mitigation in a way that also has positive outcomes for biodiversity and is an umbrella term for a number of concepts that include EbA, EbM and EcoDRR. While the term 'approaches' may have been better than 'solutions', which might be interpreted as replacing the need for cutting industrial carbon emissions, efforts to rebrand the concept would likely just hinder progress on the development and implementation of NbS. The risks of over-promise and burden-shifting from alternative approaches such as emissions reductions can be reduced and avoided through clear definition and well-communicated understanding of these risks by concerned parties, matched by efforts to codify risk reduction language in negotiated texts and implementation plans.

There is substantial evidence to suggest that there is a positive economic case for use of NbS in a range of problem contexts. Since those contexts always vary, it will always be necessary to undertake feasibility assessments to investigate potential viability and cost-effectiveness of this approach. The main barriers are financing, since NbS can involve high up-front costs, and social, since implementation often involves a change in the way that land and resource are accessed or managed, and institutional, in that implementation may not be successful in contexts where property rights are insecure or where there is weak governance. There is limited political support in developing countries, possibly due to limited evidence of its viability, as well as the relatively long time that NbS interventions take to generate benefits relative to conventional engineering projects. However support is increasing as international funds are increasingly being made available to support these efforts.

South Africa already has extensive experience in implementing NbS, particularly interventions to improve water security, and to address climate change adaptation. The guidelines already developed for EbA could easily be repurposed to be guidelines for NbS. This would expand the guidelines to include more deliberate NbS actions for mitigation, to add to existing commitments in other spheres. Monitoring efforts to date have also allowed rigorous analysis of past strategies that have been able to highlight shortcomings that need to be addressed in order to improve their efficiency. Research also suggests that there could be substantive future benefits of NbS under climate change scenarios.

Overall, the NbS concept provides opportunities to align and cohere multiple climate response options across sectors and at multiple governance scales in South Africa, including bringing together mitigation and adaptation options identified in several climate policy relevant initiatives ranging back to processes like the Long Term Mitigation Scenarios initiative from the 2000s. NbS can be linked to the achievement of Sustainable Development Goals and commitments under the CBD, providing opportunities to achieve numerous goals and targets in a more integrated way, as envisaged by concluding findings of recent cross-convention assessments by the Intergovernmental Platform on Biodiversity and Ecosystem Services. South Africa's experience in developing guidelines in Ecosystem-based Adaptation provides a strong foundation to develop nationally and regionally relevant policy to optimise opportunities and reduce the risks identified of inappropriate NbS implementation.

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| BECCS | Bioenergy with carbon capture and storage |
| BES | Biodiversity and Ecosystems Sector |
| CBA | Community-based adaptation |
| CBA | Cost-benefit analysis |
| CBD | Convention on Biological Diversity |
| CBNRM | Community-based Natural Resource Management |
| CEA | Cost-effectiveness analysis |
| DEA | Department of Environmental Affairs (now within DFFE) |
| DEFF | Department of Environment, Forestry and Fisheries (now DFFE) |
| DFFE | Department of Forestry, Fisheries and the Environment |
| EA | Ecosystem Approach |
| EbA | Ecosystem-based Adaptation |
| EbM | Ecosystem-based Mitigation |
| EcoDRR | Ecosystem-based disaster risk reduction |
| EPWP | Expanded Public Works Programs |
| GBF | Global Biodiversity Framework |
| GCA | Global Commission on Adaptation |
| GCF | Green Climate Fund |
| GIZ | Deutsche Gesellschaft für Internationale Zusammenarbeit |
| IGCCC | Intergovernmental Committee on Climate Change |
| IPCC | Intergovernmental Panel on Climate Change |
| IUCN | International Union for Conservation of Nature |
| LTAS | Long Term Adaptation Scenarios |
| M&E | Monitoring and evaluation |
| NRM | Natural Resource Management |
| NbS | Nature-based Solutions |
| NbS/A/O/I/M | Nature based Approaches/Options/Interventions/Measures |
| NBSAP | National Biodiversity Strategy and Action Plan |
| NDP | National Development Plan |
| Pers. comm. | Personal communication |
| REDD+ | Reduced emissions from deforestation and degradation |
| SANBI | South African National Biodiversity Institute |
| SDG | Sustainable Development Goal |
| UNCCD | United Nations Convention to Combat Desertification |
| UNEA | United Nations Environment Assembly |
| UNEP | United Nations Environment Programme |
| UNFCCC | United Nations Framework Convention on Climate Change |

# INTRODUCTION

Over the past decade, the concept of nature-based solutions (NbS) has gained prominence in policy, research and business efforts to advance sustainable development aspirations (Chausson et al., 2020; Seddon, 2022; Enu et al., 2023). This rise in prominence reflects the perceived utility of NbS by several actors, a view that is supported by recent inter-disciplinary scientific assessments that conclude that achieving global sustainability requires approaches that simultaneously address leading threats to climate, ecosystem degradation and biodiversity loss (Arneth et al., 2020; Shin et al., 2022; Pörtner et al., 2023). The combined challenges of climate change, environmental degradation and biodiversity loss have been assessed to increase social-ecological vulnerability to environmental hazards such as floods, storm surges, heatwaves, droughts and wildfires, highlighting both the interdependence of human wellbeing and ecosystem health, and the multiple opportunities in working with nature rather than against it (Seddon et al., 2021; IPCC, 2022; Sowińska-Świerkosz & García, 2022; Enu et al., 2023).

While the NbS concept emerged rapidly as a means to respond to the challenges of climate change and biodiversity loss, there is not yet significant unanimous support for NbS, with a number of governments, bodies and organisations unconvinced or dismissive of the NbS concept and its utility (Reise *et al.*, 2022; Seddon, 2022). This is due to two main reasons; firstly, uncertainty about when, where, how and for whom NbS may be effective, largely as a result of limited evidence and action on the ground (i.e. substantial knowledge gaps) and secondly, controversies that have arisen due to the perceived misuse of NbS (e.g. accusations of greenwashing and inadvertent or unintended threats to biodiversity; Chausson *et al.*, 2020; Seddon, 2022; Castelo, Amado & Ferreira, 2023). Examples include over-emphasis on afforestation (e.g. using non-indigenous species in in tree-planting campaigns in naturally treeless ecosystems such as grasslands, referred to as maladaptation), rather than investing in a wide range of ecosystems (Seddon, 2022). Concerns have also been raised that promoting nature-based “solutions” may lead governments to believe that they can relax their attention on reducing industrial emissions, as nature can take care of the problem. In addition, support and uptake in the global South, particularly sub-Saharan Africa, has been relatively poor (Nyika & Dinka, 2022; Enu *et al.*, 2023; Woroniecki *et al.*, 2023), due to concerns about its alignment with development objectives as well as the greater challenges associated with implementation in these regions. There is a need for further clarity on the scope, principles and use of NbS within different ecological, socio-ecological, and engineering system contexts in the region.

Nature-based solutions are increasingly entering the international policy arena, such as the recently-finalised Kunming-Montreal Global Biodiversity Framework, which outlines 23 interlinked and interdependent targets in three broad areas of intervention (Figure 1). The widespread confusion around NbS is reflected in the expanded description of Target 8. This target, which falls within the focus area on reducing threats to biodiversity, is to minimise climate impacts on biodiversity. However, its description confusingly reflects the need to implement “nature-based solutions and/or ecosystem-based adaptation” in order to do so, whereas such terms are usually associated with addressing impacts on *human society*, and it is the view of the authors that this could have been more suitably included under Target 11 (which is about securing and enhancing the supply of ecosystem services).

The confusion and concerns around NbS have led to some nations, including South Africa, withholding unequivocal support for its inclusion in international agreements and domestic policy, pending greater clarity and a more balanced assessment of the risks and opportunities. This research was therefore commissioned to assist South Africa’s Department of Forestry, Fisheries and

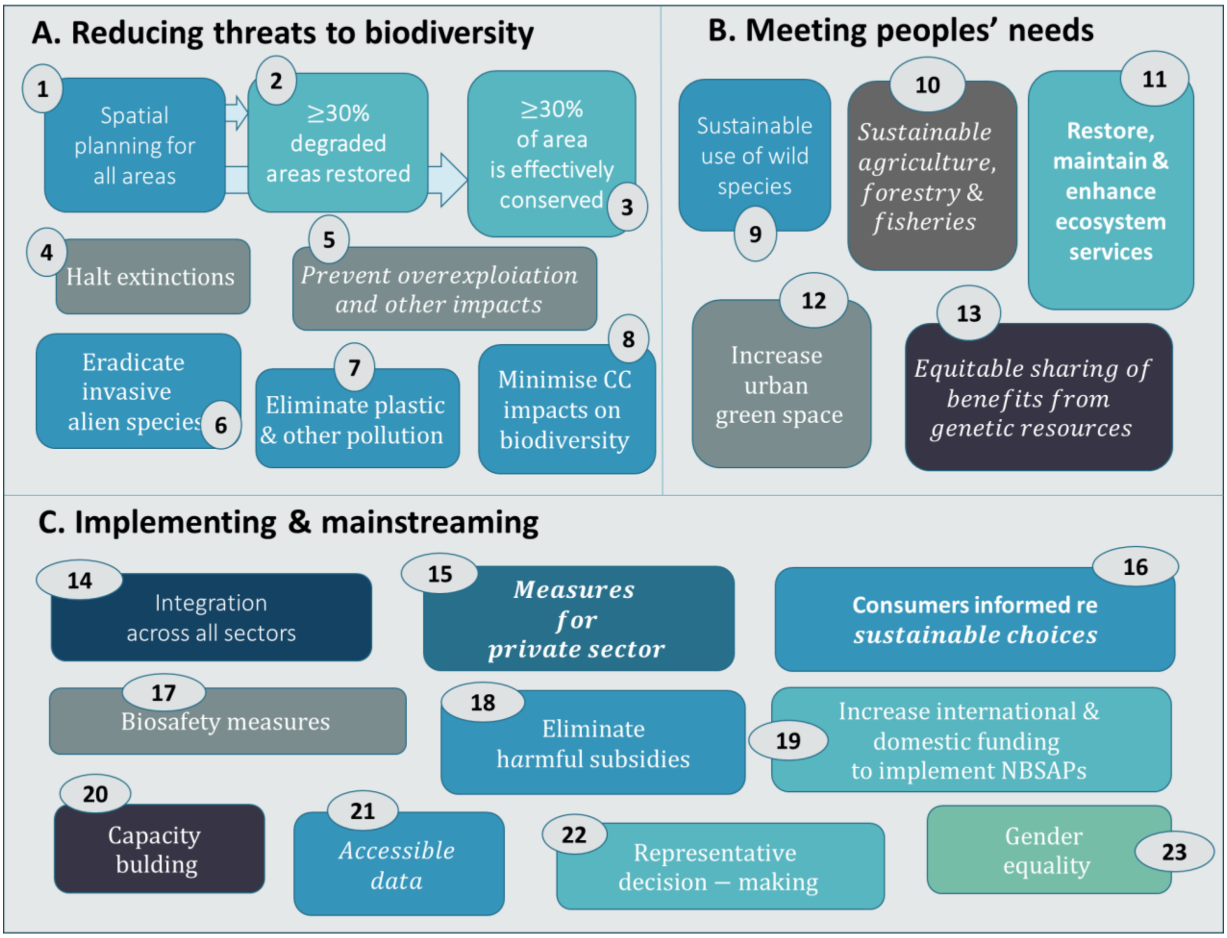



Figure 1. A summary of the 23 targets of the Kunming-Montreal Global Biodiversity Framework. Source: Authors.

Environment (DFFE) to provide improve understanding of the concept and viability of NbS in general, and how this can guide its use in South Africa to ensuring its successful alignment with the country's development priorities as well as its environmental obligations. The specific objectives of the review were:

- to provide clarity on the concept of NbS, particularly in the context of addressing climate change;
- to collate evidence on the viability and cost-effectiveness of NbS compared with "conventional" approaches;
- to describe the challenges in implementing NbS, and how these might apply to the South African context; and
- to review NbS best practices and provide guidance for South Africa.

The assessment was based on a review of relevant literature, particularly the many recent global and regional reviews on the topic and including some key "grey literature" sources reflecting developing thinking by various actors. The review included peer-reviewed scientific articles, technical reports, best practice guideline documents, party submission documents, and websites of key institutions and development agencies involved in gathering and evaluating information on concepts and definitions, typologies, and criteria, and the benefits and limits of nature-based solutions.

# CONCEPTUAL OVERVIEW

## DEFINITIONS OF NATURE-BASED SOLUTIONS

One of the key problems in the NbS literature and conversations is the lack of clarity on what NbS is and what it is not. This confusion is fuelled by major differences in widely used and cited definitions, as well as by the growing number of related terms.

In 2008, the first publication on NbS by the World Bank (Mackinnon, Sobrevila & Hickey, 2008) did not explicitly define the term NbS. Since then, two definitions (or slight variations thereof) have become the most widely used in the literature, from the International Union for Conservation of Nature (IUCN; Cohen-Shacham *et al.*, 2016) and the European Commission (European Commission, 2020; Table 1).

Table 1. Definitions of NbS. Colours indicate comparable elements of text.

| Source | Definition of NbS |
|---|---|
| IUCN 2016 | Actions to protect, sustainably manage and restore natural or modified ecosystems, which address societal challenges (e.g. climate change, food and water security or natural disasters) effectively and adaptively, while simultaneously providing human well-being and biodiversity benefits. |
| European Commission 2020 | Nature-based solutions to societal challenges are solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions. NbS must benefit biodiversity and support the delivery of a range of ecosystem services. |
| UNEA 2022 | Actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services and resilience and biodiversity benefits. |
| Proposed, this study | Actions to protect, sustainably manage and restore natural or modified ecosystems to secure ecosystem services to address societal challenges and improve wellbeing, and which are also beneficial for biodiversity. |

The IUCN definition focuses on improving the status of natural or modified ecosystems to address societal challenges. The EU definition (the 2020 version having updated an earlier 2015 version) is notably different from the IUCN definition in that it includes solutions that are "inspired by … nature". Their definition does not mention ecosystems and refers to the use of "nature and natural features and processes" which is broader. The area of overlap rests largely on what constitutes a "modified ecosystem", and notably, whether it includes "created ecosystems" (or something akin to this), which is not mentioned in any of these definitions but hinted at by "inspired by". This begs the fundamental question as to the meaning of "nature-based" and is discussed further below.

More recently, the Fifth Session of the United Nations Environment Assembly (UNEA-5) made a resolution on adopting a multilaterally agreed definition of NbS (Table 1) based mainly on the IUCN (2016) definition, but adds detail on broad types of ecosystems, and elaborates on the human well-being aspect by adding "ecosystem services and resilience" (Reise *et al.*, 2022). This is the definition that has since been accepted by the South African Government (B. Kgope, DFFE, pers. comm.). However, the UNEA definition, while adding "ecosystem services" does not convey the idea that it is the ecosystem services generate through the actions that are being used to address the societal challenges. We also propose a simpler definition with less redundancy (Table 1).

## WHAT DOES "NATURE-BASED" ENCOMPASS?

Some of the difficulty in reaching a common understanding of NbS is due to the different ways that people understand terms such as "nature" and "ecosystem" (Ducarme & Couvet, 2020). This because the terms have evolved and expanded in their usage.

Nature is defined as "the phenomena of the physical world collectively, including plants, animals, the landscape, and other features and products of the earth, as opposed to humans or human creations" (Oxford English Dictionary). Thus nature-based can be construed as making use of any of these elements of nature. In other words, it can be about using ecosystems, for example to deliver ecosystem services, or using "exotic" species that are used outside their natural environment, such as planting trees for shade, which is now also considered as an ecosystem service in an urban context.

The IUCN and UNEA definitions of NbS name "natural or modified ecosystems" as the site of interventions. An ecosystem is a system of interacting and interdependent organisms and their physical environment. They can be defined at different scales, as they can be nested within one another (e.g. a coral reef ecosystem within a marine ecosystem). A natural ecosystem can be thought of as one that has not been significantly altered by human activities. However, the word "modified" is a little less clear, and could mean anything from a slightly changed to completely rebuilt. "Modified" could mean that wild herbivores are replaced with domestic livestock (rangelands), or that all of the original plants and animals (other than subsoil species) are replaced by a few or one food or tree species (cultivated areas). It could also mean reservoirs, purpose-built wetlands or even vegetated swales, which completely replace one type of ecosystem with another that is created from elements of ecosystems occurring elsewhere. Indeed, this appears to be the very broad concept of "natural or modified ecosystems" that are encompassed in the NbS literature, including in examples given by IUCN (2020), which mention sustainable agricultural practices and urban vegetated swales as NbS.

A more appropriate definition, therefore, would use the words "natural, modified or man-made ecosystems". This aligns with the figure used in the IUCN's (2020) "Global Standard for Nature-based Solutions" (Figure 2). This figure conveys the idea that increased complexity associated with more intact natural ecosystems can deliver more services to people. Indeed, relatively intact ecosystems tend to have higher levels of complexity and biodiversity and are generally valued for their capacity to supply regulating ecosystem services, in particular. Some of this complexity is lost through management of natural systems, such as for the extraction of their provisioning services, which depending on the level of sustainability, can compromise ecosystem capacity to deliver a range of services. At the other end of the spectrum are man-made ecosystems that tend to be structurally simple and focus on the provision of a single service such as crops, timber or water, at the expense of most other services. Nature-based solutions secure or reintroduce some of the original ecosystem complexity to maintain or improve resemblance to a natural structural and functional state. In so doing, they help to alleviate or prevent the loss of biodiversity. The fundamentals of NbS are derived from established practices such as integrated water resource management, ecosystem-based adaptation and mitigation and ecosystem-based disaster risk reduction, which have been promoted since the 1990s, long before the term 'NbS' arose (IUCN 2020).

While man-made ecosystems such as croplands are not typically included in the meaning of "nature", the term "ecosystem" has been somewhat appropriated by those who support the modification of ecosystems, leading to the expanded definition of ecosystem we now see in the UN's System of Environmental Economics Accounting for Ecosystem Accounting (UN et al., 2021). Thus, the term NbS is used for activities in cultivated systems (agriculture, aquaculture, silviculture). In cultivated settings, what makes interventions nature-based, as opposed to regular sectoral interventions, is that they are not just focused on the producer but are designed to enhance ecosystem services such as sediment retention, which can contribute to water security, for example, as well as reducing negative impacts of sedimentation on aquatic biodiversity. In the case of engineered systems, the creation of the system itself is the nature-based solution, and it may replace a built structure.

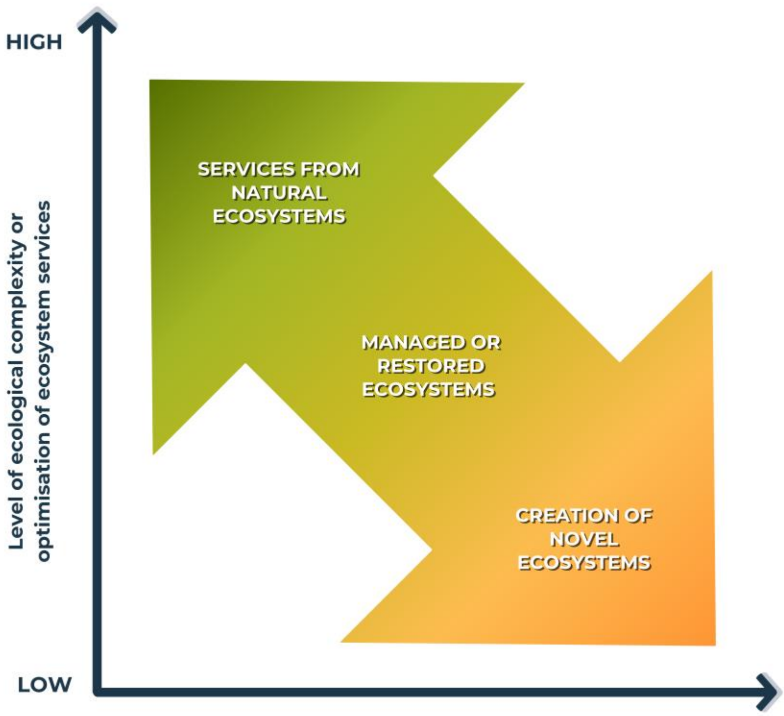



Figure 2. NbS are measures or actions that can be implemented along a continuum – from intact natural ecosystems to managed ecosystems to man-made ecosystems. Source: adapted from Eggermont et al. (2015); Miralles-Wilhelm & Iseman, (2021).

While the inclusion of croplands suggests that many regard cultivated areas as modified ecosystems as opposed to man-made ecosystems, it is more difficult to understand the inclusion of engineered ecosystems (also termed created ecosystems, such as wastewater treatment wetlands). The use of engineered systems does not strictly fit the definition that NbS are "actions to protect, sustainably manage and restore natural or modified ecosystems" unless the systems themselves are designed to reduce negative impacts on downstream ecosystems that deliver important ecosystem services. However, they are generally considered to include engineered ecosystems that have biological elements, and not those such as porous paving, for example, which is designed to mimic natural infiltration, but without the use of any living element (see discussion below). Thus, we can view NbS as being designed to secure, restore ***or assemble (engineer)*** some or all of the elements of a natural system to improve the supply of particular provisioning, regulating or cultural services that can alleviate the challenge being addressed.

Thus NbS are not simply ‘nature derived’ (come from the natural world) such as wind or solar energy, nor are they simply ‘inspired by nature’ (modelled on biological processes) such as biomimicry, as none of these are directly based on functioning ecosystems (Reise *et al.*, 2022; Sowińska-Świerkosz & García, 2022). Rather the focus of NbS activities is on the protection, restoration and sustainable management or creation of ecosystems to increase their capacity to provide ecosystem goods and services (Cohen-Shacham *et al.*, 2016; Seddon *et al.*, 2021).

In terms of their ecological setting, the following types of ecosystems can be used to deliver nature-based solutions, noting that the first is the one that satisfies all definitions, while the others may not:

- **Natural and semi-natural ecosystems:** These include intact to moderately-modified systems where locally-indigenous flora and fauna still dominate and where their community structure still bears at least moderate resemblance to its original state before the influence of man. They include ecosystems managed as rangeland areas (where the grazer/browser species have been changed) or managed for the harvesting of indigenous/wild resources. While such areas can be highly degraded as a result of poor management (i.e. involving further deviation from natural condition), they would still be included in this category. Here, NbS involve improving or maintaining the condition of these ecosystems to secure the supply of a combination of regulating, cultural and/or provisioning services.

- **Cultivated ecosystems:** These are anthropogenic or man-made ecosystems designed to maximise provisioning services, and whose flora and/or fauna are usually intentionally dominated by introduced, and sometimes engineered, species. They include crops, orchards, planted pastures, tree plantations and aquaculture systems. Here, NbS involve improving regulating services delivered from these systems, often with the added benefit of improving their provisioning value.

- **Engineered ecosystems:** These are anthropogenic or man-made, purpose-built ecosystems that are engineered to produce regulating services such as water quality amelioration or surface flow retardation, using biological elements of nature. They are usually established in urban or other settings that bear little or no resemblance to the original land cover. In this case, the NbS involves the creation of these systems.

## ADDRESSING SOCIETAL CHALLENGES THROUGH NBS

The ways in which sectoral challenges such as water supply and food security have been addressed in the past have often involved negative impacts on the environment and undermined system resilience. Examples include constructing additional water supply infrastructure in response to water scarcity, despite impacts on downstream ecosystems, and incentivising industrial monocultures that waste water and pollute rivers, or failing to invest in sustainable practices, resulting in needless losses of soil and water. Nature-based solutions offer alternatives to conventional approaches of addressing societal challenges that work with, rather than against, nature. Some of the societal challenges that have the potential to be addressed using NbS include the following:

- **Livelihood/income security**: Sustainable management of harvested resources and biodiversity that bring income through farming, trade and tourism;

- **Water security**: Restoring and securing hydrological ecosystem services, including flow regulation and water quality amelioration, sediment retention and flood attenuation, through restoration and protection of natural vegetation cover in catchment areas, riparian areas and wetlands, and through construction of treatment wetlands in urban areas;
- **Food security**: Implementation of conservation farming methods to improve soil and water retention and improve small-scale crop yields;
- **Mitigating heat stress**: Retaining urban green space areas and wetlands and planting street trees to provide shade, deflect radiation, and increase cooling through evapotranspiration.
- **Disaster risk management - flooding**: Restoring and maintaining natural vegetation cover in catchment areas and riparian areas to enhance infiltration and retard flood flows; maintaining mangrove and dune ecosystems to act as natural barriers to mitigate coastal storm surges; creating vegetated swales and basins and green roofs to retard storm flows in urban areas;
- **Disaster risk management - wildfire**: Restoring degraded habitats, removing invasive alien plants (IAPs), prioritizing fire-resistant vegetation, enabling grazing by herbivores in areas facing land abandonment, and undertaking prescribed burns.
- **Disaster risk management - drought**: Removal of water-using IAPs from catchment areas, conservation farming measures and climate smart agricultural practices that reduce the risks of failure in drought;
- **Mental and physical wellbeing**: Providing natural amenities, such as green open space, parks, etc. in urban areas, as well as protection of biodiversity and wilderness areas to alleviate global anxiety about the loss of these.

Some examples of the difference between conventional measures and NbS in addressing challenges are given in Table 2, along with an explanation of how these measures may relate to one another. In some cases they are complementary to conventional infrastructure, for example through prolonging its lifespan or reducing its maintenance costs. In other cases, NbS can be seen as substitutes for conventional measures. NbS can also be used in combination with elements of grey infrastructure, e.g., sustainable drainage systems (SuDS), and may include engineered ecosystems in urban areas (Reise *et al.*, 2022), or changed management systems in cultivated areas (Miralles-Wilhelm & Iseman, 2021).

## NBS SIMULTANEOUSLY ADDRESS CLIMATE CHANGE ADAPTATION, MITIGATION AND (OFTEN MULTIPLE) SECTORAL CHALLENGES

Whereas NbS interventions are commonly implemented to address a primary or “sectoral” challenge such as those outlined above, many are implemented specifically as a means of addressing climate change adaptation or mitigation. However, there are strong overlaps between these objectives, and the same actions or NbS can simultaneously address adaptation and mitigation as well as sectoral challenges. Recognition of the relationship between the sectoral objectives/outcomes and the climate-related objectives/outcomes helps to alleviating some of the confusion around NbS and related terminology.

Table 2. Examples of how problems are typically addressed using conventional and nature-based measures, and the complementary or substitution relationship between these two broad types of approaches which forms the basis of understanding of their potential cost-effectiveness.

| Sectoral objective | Conventional measures | Nature-based measures | Relationship |
|---|---|---|---|
| **Water supply (quantity)** | Construct dams | Maintain rainfall infiltration and stream flows by maintaining natural vegetation cover in catchment ecosystems | Complementary, more storage required in absence of nature-based measures |
| **Water quality** | Water treatment plants | Maintain water quality amelioration services provided by healthy natural catchment vegetation and wetlands;<br>Build artificial treatment wetlands to polish treated wastewater | Complementary, more chemicals are used in absence of nature-based measures |
| **Food security** | Industrial-scale irrigated monocultures treated with fertilisers and pesticides | Conservation farming methods to improve soil and water retention and improve small scale crop yields | Substitutes, NbS allow more affordable food security with lower environmental impact |
| **Reducing flood risk** | Concrete levees, canals and other conveyance infrastructure | Reduce the rate of stormflow runoff by maintaining infiltration through natural vegetation cover in catchment areas; reduce coastal storm damage by maintaining mangrove and dune ecosystems; retard storm flows through using vegetated swales and basins, and through green roofs (porous paving is an alternative, green measure). | Complementary, more conveyance infrastructure required in absence of nature-based (or green engineering) measures |
| **Reducing wildfire risk** | Fire suppression and fire exclusion policies. | Reduce wildfire risk by restoring degraded habitats, removing IAPs, prioritizing fire-resistant vegetation, promoting less fire-prone forests, enabling grazing by herbivores in areas facing land abandonment, and doing prescribed burns. | Substitutes, implementation of NbS improves fuel management and reduces wildfire risk. |
| **Mitigating heat stress** | Reduce exposure, appropriate clothing, air conditioning. | Shade, deflecting radiation, releasing moisture into atmosphere through urban greening (urban green space, street trees, green roofs and walls). | Complementary, more conventional measures used in absence of nature-based measures |
| **Improving mental and physical wellbeing** | Gyms, mental health services | Provision of natural amenities especially in urban areas | Complementary, more conventional measures required in the absence of natural amenities such as green open space. |

NbS that are designed to increase resilience or adaptation to climate change are also called Ecosystem-based Adaptation[1] measures, while those designed to increase carbon sequestration or storage are termed Ecosystem-based Mitigation measures. These are both subsets of NbS, that also tend to deliver multiple benefits.

Where a sectoral challenge is the stated objective, addressing this challenge invariably contributes to either climate change adaptation/resilience, depending on the level of climate-change vulnerability in the context of the activity. Conversely, where the stated objective is climate change adaptation (or improved resilience), the NbS measures are usually designed to address sectoral challenges as the means to achieve this.

NbS is also commonly applied in the context of climate change mitigation. These interventions are designed to reduce carbon emissions or to increase carbon sequestration and storage by improving the protection and condition of natural and cultivated ecosystems. Because NbS measures to address sectoral challenges or overall resilience often also involve improving the protection and condition of ecosystems, they generally also contribute to climate change mitigation.

Finally, because ecosystems produce multiple types of ecosystem services, interventions that secure or improve ecosystem condition usually also produce a range of co-benefits. This is one of the reasons that NbS can prove to be viable despite the fact that restoration and protection of ecosystems can be notoriously costly.

## NBS IN THE CONTINUUM OF CONSERVATION TO ENGINEERING INTERVENTIONS

NbS are generally posited as alternatives to conventional engineering solutions to address a wide range of societal challenges, such as those listed in Table 2. However, the distinction between these two types of solutions is not always clearcut. Figure 3 outlines a range of sectoral challenges for which NbS could play a role, and a simple typology of engineering, green and nature-based approaches that can be used to address these. It is important to note that all of these challenges can be addressed or supported using NbS and all contribute to meeting larger objectives of climate change adaptation or mitigation.

Conventional engineering interventions (often termed 'grey infrastructure') typically serve a single purpose, are effective only in the short- to medium-term, are relatively capital intensive, and often have negative impacts on natural ecosystems (Singhvi, Luijendijk & van Oudenhoven, 2022; Enu *et al.*, 2023). This has led to the awareness that a hybrid approach could be more efficient and effective where NbS are considered a complement to conventional engineering approaches, increasing the effectiveness of these investments, and potentially reducing some long-term costs. This has become increasingly important as a comprehensive strategy in an uncertain future, highlighting the need for adaptability and resilience to changing climatic conditions. With time, this has led to a spectrum of principles that range from grey to green infrastructure, hard to soft interventions, or engineered to natural ecosystems (Mulligan *et al.*, 2020; Singhvi *et al.*, 2022; Figure 2). This

[1] As per South Africa's EbA Strategy 2025-2034, ecosystem-based adaptation (EbA) is defined as "The use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change" (CBD 2009). This fits entirely within the definition of NbS.

continuum of approaches has made it difficult to conceptualise and confine specific terms and concepts to a particular "box".

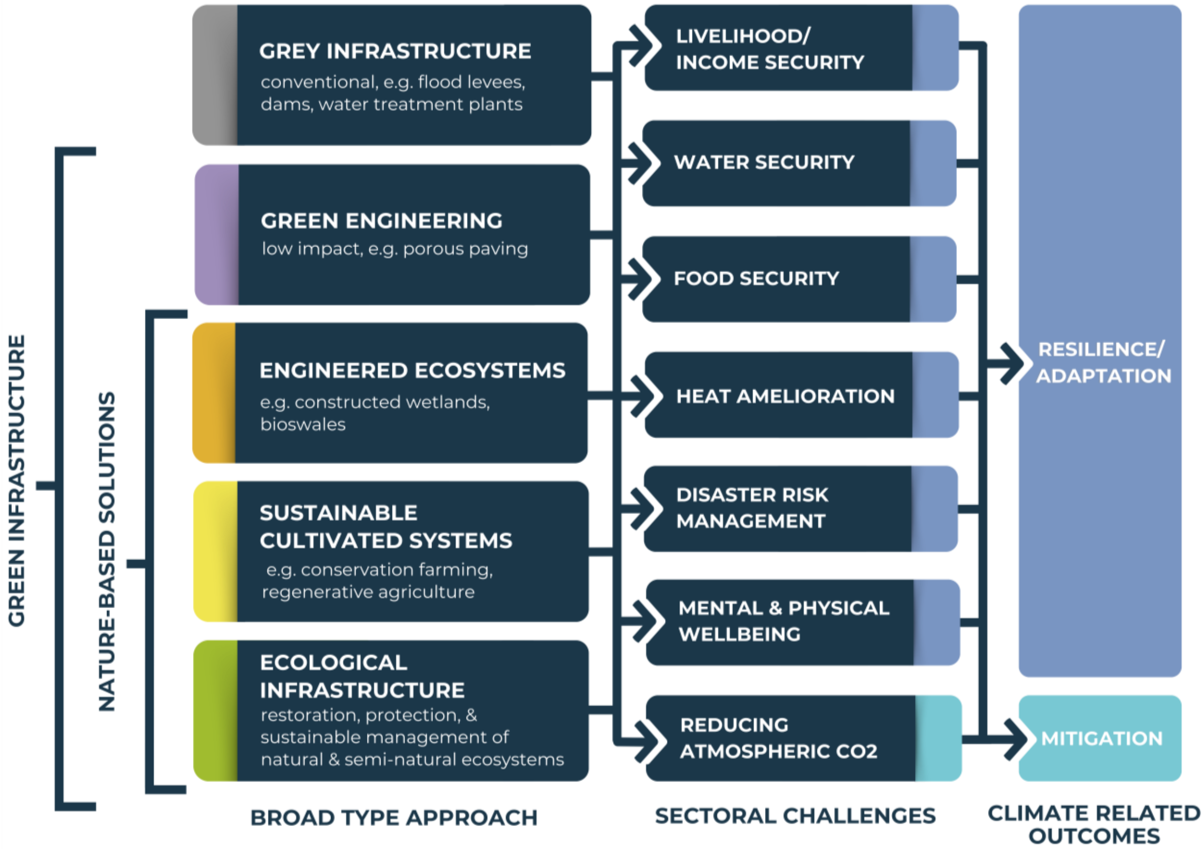



Figure 3. How green and nature-based solutions fit into the continuum of natural to engineering approaches used to address societal challenges, and the associated sectoral and climate-related outcomes. Source: Authors.

It is difficult to separate exactly where nature-based and engineering solutions start and end because of the element of overlap with an engineering continuum which has resulted in hybrid measures (a combination of green and grey elements), often referred to as the 'grey-green spectrum' (Singhvi *et al.*, 2022) or 'green-hybrid-grey spectrum' (Anderson *et al.*, 2022). For example, sustainable urban drainage systems (SUDS) are set of specific techniques that are nested within the broader framework and principles of green infrastructure (GI) – all of which are considered NbS for urban drainage (Mulligan *et al.*, 2020). Many SUDS, such as green roofs, permeable paving, underground detention and vertical greening systems are considered hybrid approaches (Enu *et al.*, 2023). It is important to note that the use of the word "green" usually refers to products or approaches that are environmentally friendly but not necessarily biological. Therefore, there is a very important distinction between "green infrastructure" (environmentally friendly) and "ecological infrastructure" which comprises functioning healthy ecosystems that deliver regulating services at full or high capacity (i.e., excluding intensive crop "ecosystems").

NbS are commonly considered separately from traditional grey infrastructure, even though they can provide co-benefits to conventional solutions for water supply, food security and energy (Nelson *et al.*, 2020). In some cases, they can be implemented in combination as hybrid approaches to deliver more cost-effective and climate resilient services (Sutton-Grier, Wowk & Bamford, 2015; Browder *et* *al.*, 2019; Seddon *et al.*, 2020). For example, water supply can be increased through investing in reservoirs, treatment plants and the piped network; but additionally, investing in wetlands could filter wastewater effluent and therefore reduce wastewater treatment requirements (Browder *et al.*, 2019). Compared to traditional solutions, NbS are dynamic and heterogeneous; they can perform multiple functions under multiple future conditions; and they can self-repair if damaged by natural disasters (Nelson *et al.*, 2020). NbS can also provide positive benefits to communities through their participation in project operations (Browder *et al.*, 2019).

Hybrid systems seem best developed in hydrological settings, for drainage systems in urban areas and on shorelines or coastal areas. China's Sponge City Program (SCP) which envisions a surface water system to function like a sponge, uses different combinations of measures to improve stormwater retention, storage, treatment and infiltration (Hamidi, Ramavandi & Sorial, 2021). The SCP stresses the importance of using natural and natural-engineering hybrid measures to mimic the natural water cycle (Hamidi *et al.*, 2021). In coastal systems, ecological engineering alternatives for traditional coastal protection infrastructure are becoming more widespread in areas where maintaining a natural shoreline is not possible (Smith *et al.*, 2020). These approaches tend to rely on a combination of natural or living material and built (grey) infrastructure to provide shoreline protection as well as an element of restoration. The term 'living shorelines' is now commonly used to refer to novel restoration projects for shoreline protection (Smith *et al.*, 2020). These shoreline designs fall along the green-grey spectrum, from vegetative plantings (reforestation) on the green end to habitat restoration in combination with structural materials on the grey end (Smith *et al.*, 2020). These approaches may have multiple benefits, including climate change mitigation, especially with regards to the restoration and protection of mangrove forests.

In summary, NbS includes measures that secure ecosystem services from natural, man-made or engineered systems, which include agricultural land and constructed wetlands, but does not include built interventions that are low impact but do not involve biological elements or resemble 'ecosystems' (Figure 1). However, it is important to note that NbS are frequently implemented in combination with other ("green" or "grey) engineering solutions, where these act synergistically in support of the overall objective.

## KEY CHARACTERISTICS OF NBS

In arriving at the UNEA (2022) definition, a set of six key characteristics or criteria of NbS were described to better define the scope (concept boundaries) and types of interventions that would qualify as NbS, namely:

- alignment with natural ecosystem processes;
- benefitting biodiversity;
- adaptability;
- being locally appropriate;
- being multifunctional; and
- enhancing human wellbeing.

These criteria, which are described in more detail in Table 3, also help to define what are not NbS. For example, actions that exploit nature and damage biodiversity in the process, such as negative emissions technologies (e.g., bioenergy with carbon capture and storage; BECCS) or commercial monoculture plantations (afforestation), which are known to disrupt ecosystem processes, transform or fragment habitats and are directly harmful to species, do not fulfil NbS requirements

(Figure 1; Sowińska-Świerkosz & García, 2022).[2] In addition, to maintaining a system's natural adaptability (Reise *et al.*, 2022; Sowińska-Świerkosz & García, 2022), the IUCN's Global Standard for NbS (IUCN, 2020) states that NbS implementation plans should consider the uncertainty that is integral to ecosystem management (due to their complex and dynamic nature) and be managed adaptively based on evidence. The last criterion is what separates NbS from traditional conservation approaches which focus on the protection of individual species or habitats without due consideration for societal challenges and human well-being (IUCN, 2020; Reise *et al.*, 2022).

Table 3. The six defining characteristics of NbS. Source: Reise *et al.* (2022).

| Key characteristics | NbS | Non-NbS |
|---|---|---|
| **Alignment with natural ecosystem processes** | Use natural ecosystem processes (e.g., $CO_2$ uptake by photosynthesis and biomass build-up which can be used in a diverse cascade by different organisms of the specific ecosystem); build on ecosystem capacity for self-regulation, renewal, nutrient cycling and the provisioning of various services. | Lacks alignment with natural ecosystem processes; require an ongoing and significant human intervention using engineered structures, ongoing provision of energy or water; lead to soil sealing and ecosystem destruction. May come from natural world or be modelled on biological processes but is not directly based on functioning ecosystems. |
| **Benefit biodiversity** | Benefits for biodiversity are achieved by protecting and restoring natural ecosystem processes. They support the adaptive capacity and quality of ecosystems and habitats. Can damage biodiversity by disrupting natural ecosystem processes, removing or fragmenting habitats or directly harming habitats and species. | Can damage biodiversity by disrupting natural ecosystem processes, removing or fragmenting habitats or directly harming habitats and species. |
| **Adaptability** | Is planned in a manner that supports the natural adaptability of ecosystems. | Does not include considerations of adaptability and ecosystem resilience. |
| **Locally appropriate actions** | Consider local economic and social conditions and use native species. | Uses non-native species; does not consider the characteristics, importance and ecological resilience of local ecosystems; is not designed with the local social and economic conditions in mind. |
| **Multi-functional** | Provides numerous (co-)benefits in parallel for people and the environment. | Focuses specifically on one objective and/or does not generate additional ecosystem services. |
| **Address societal challenges and enhance human well-being** | Provides benefits to human well-being and helps to address societal challenges. | Focuses on conservation, biodiversity or other objectives, without considering how they address societal challenges. |

[2] There might be limited exceptions e.g. in cases where these are implemented on badly degraded land / abandoned agricultural land

## A TYPOLOGY OF NBS

Various authors have devised typologies of NbS. The IUCN and EC both categorise NbS according to challenges addressed, with the IUCN having five groupings (Cohen-Shacham *et al.*, 2016) and the EC having seven groupings (European Commission, 2015). However, there is some overlap in the groupings which makes the categorisation somewhat confusing. Cohen-Shacham *et al.* (2019) categorised NbS as restorative, issue-specific, infrastructure, management, or protection. However these are not necessarily mutually exclusive. Seddon *et al.* (2020) organised NbS according to whether they reduced exposure, reduced sensitivity, or supporting adaptive capacity of socio-economic systems. The European Environment Agency (EEA) grouped NbS for climate hazards into five thematic areas relating to landscape location – water management, forests and forestry, agriculture, urban areas, and coastal areas (EEA, 2021). Skrydstrup *et al.* (2022) characterised NbS for urban flooding by landscape/ecosystem type, as did Enu *et al.* (2023) in their review of NbS in Sub-Saharan Africa and the World Bank in their review of NbS for climate resilience (Van Zanten *et al.*, 2023). The latter report categorised NbS into 11 "families" based on the type of ecosystems they were applied in, namely urban and upland forests, terraces and slopes, rivers and floodplains, urban green areas, waterbodies, inland wetlands, mangrove forests, other coastal wetlands, reefs, submerged aquatic vegetation and sandy shores and dunes.

Along the lines of EEA (2021) and Seddon *et al.* (2021), and building on Figure 3, a relatively simple typology of NbS is devised here in order to frame the discussion in the rest of this document (Figure 4). Here it is proposed that NbS interventions can be usefully characterised in terms of a simple breakdown of (a) where they are implemented (the context), (b) the type of actions that are undertaken, pertaining to level of ecosystem modification, and (c) their primary purpose (Figure 4):

- **Four broad settings** can be identified in which NbS activities tend to involve quite distinct types of actions: (1) terrestrial landscapes including their freshwater ecosystems (2) coastal areas (3) cultivated areas and (4) urban areas (which encompass some of the above).
- Within these, **three main types of actions** are: (1) protection, restoration and sustainable management of natural and semi-natural ecosystems as alternatives to their overexploitation or conversion to other use, (2) rotational, regenerative or agroforestry practices in cultivated areas that better retain soil, water, carbon and biodiversity, and (3) creation of purpose-built ecosystems as alternatives to grey engineering solutions.
- In this typology, we recognise **six types of sectoral challenges** being addressed that also address climate change adaptation, plus climate change mitigation.

Protection, restoration and sustainable management of natural and semi-natural ecosystems mainly takes place in natural inland and coastal ecosystems, but also in natural spaces within urban contexts. These actions are implemented to secure valuable "ecological infrastructure", i.e. ecosystems that are important in terms of provision of regulating services that can complement or provide substitutes for built infrastructure, particularly in the context of water security (e.g. sediment retention in water supply areas, or flood attenuation in urban areas). They may also be implemented to secure provisioning and cultural services that contribute to food and income security, e.g. by restoring the stocks and productivity of utilised resources, and by restoring biodiversity and landscape beauty, respectively. Opportunities for this tend to be more limited in highly developed countries, but are very significant in sub-Saharan Africa (Enu *et al.*, 2023). These types of actions would include:

- Introducing or strengthening area-based protection from a range of threats;

- Active reintroduction of plant and animal populations in disturbed or semi-natural landscapes;
- Clearing and control of invasive alien species or excessive bush encroachment;
- Active removal of engineering measures that have damaged ecosystems (e.g. Removal of dams or restoring natural riparian form from canalised river systems);
- Active restoration and protection of degraded and eroded rangeland areas, of riparian vegetation and of wetlands;
- Passive restoration and maintenance of landscape health through introduction of sustainable grazing practices and appropriate fire management; and
- Revegetating foreshore areas in coastal areas.

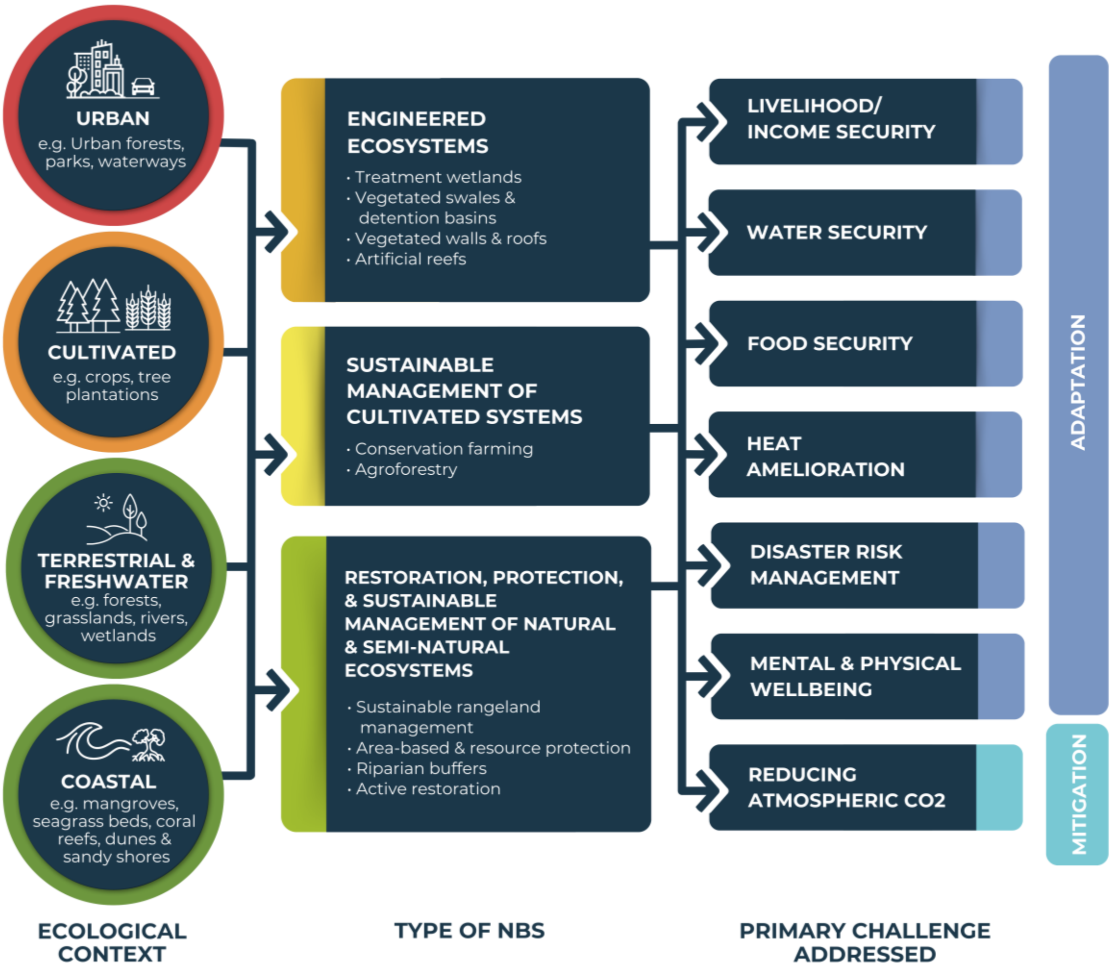



Figure 4. Elements of a three-way typology of NbS, with four broad categories of ecological context, three broad categories of NbS actions, and seven broad categories of the primary or sectoral challenges that they address. Examples are not exhaustive. Source: Authors.

NbS relating to cultivation practices are focussed on existing agriculture, silviculture or aquaculture areas, not the expansion of these areas. They involve changing the way that cultivated systems are managed in order to restore their capacity to supply regulating as well as provisioning services, thereby also reducing damages as a result of soil and water losses, as well as measures to reduce damaging activities that result in environmental pollution. These actions would include conservation agriculture practices such as no-till and mulching, as well as agroforestry and organic farming, and often come with a co-benefit of improved food production (Enu et al. 2023).

Creating novel, engineered ecosystems (other than cultivated systems) occurs mostly within urban and coastal areas which are the most transformed/modified ecosystems. Some examples within the more built environment contexts include[3]:

- Planting street trees for amenity and local air quality and temperature regulation in urban areas;
- Constructing vegetated swales (bioswales) and detention basins to promote retardation of stormwater flows;
- Constructing wetlands to polish treated wastewater effluents; and
- Establishing vegetated walls and roofs.

It should be noted that most of the discussion on NbS, and in particular, NbS typologies, has focused on what might be referred to as direct actions such as the examples given above. In addition to these, and relevant to the economic analysis of NbS, are accompanying supporting or enabling actions that are designed to ensure that the actions can be optimally implemented, and which are typically commenced before the direct actions. Direct NbS activities and their supporting actions are explicitly distinguished in the glossary developed by The Economics of Ecosystem Restoration (TEER) initiative of the FAO[4]. Supporting actions include changes in legislation, implementation of participatory processes, integration with planning processes and capacity building. While not included in the typologies of NbS actions, supporting actions are often essential to the uptake and success of NbS and are an important element to be included in planning and costing.

## SHOULD THESE ACTIONS BE CALLED "SOLUTIONS"?

There has been some concern among policymakers of the use of the word 'solutions' in NbS, and some have suggested changing this to a term such as "approaches". NbS are promoted as solutions for a wide range of problems, such as water security (maintaining water supply, water quality or controlling flood flows), food security, basic human needs (like materials for shelter), disaster risk management (exposure to floods, exposure to sea level rise, impact of droughts), and mental and physical wellbeing. The term 'solutions' was used to convey the view of nature as being helpful in achieving these aims (Nesshöver et al., 2017). However, there are concerns that this implies that nature can fully take care of the problem. This concern relates mainly to the use of NbS in the context of climate mitigation, where an inflated sense of the role of NbS could engender false confidence and even encourage burden-shifting from more directly relevant actions, such as the reduced use of fossil fuels.

The scientific literature does not pose NbS to be the final solution to any of these problems, but rather a set of actions that can contribute to alleviating them. Moreover, it also advises caution with regard to the level of reliance on NbS, suggesting that it should be framed as an addition or a complement to other solutions, such as required reductions in fossil fuel emissions (in the context

[3] Note that the interventions associated with cultivated, terrestrial, freshwater and coastal ecosystems can also occur in urban areas where elements of these systems occur.

[4] TEER | The Forest and Landscape Restoration Mechanism | Food and Agriculture Organization of the United Nations (fao.org)

of mitigation) and approaches to eliminate damaging activities on ecosystems caused by current patterns of production and consumption (i.e., global consumerism; Reise et al., 2022; Seddon, 2022; Castelo et al., 2023). Reliance on NbS to offset emissions or harmful activities elsewhere has been strongly discouraged (Mardirossian & Arnold, 2023).

Indeed, some concerns have also been raised that the realistic potential for NbS may be overestimated (Reise et al., 2022), particularly for climate change mitigation, due to over-optimistic estimates of land availability for NbS, incomplete consideration of proposed activities that ignore displacement ('leakage'), dismissal of non-carbon forcing effects (e.g. albedo effects) of NbS activities, unintended consequences for human livelihoods, poor baseline information on ecosystem services and biodiversity, inadequate knowledge of local ecosystem functioning (e.g. carbon sequestration), vulnerability to climate change, socio-economic considerations, and non-permanence. Therefore, while NbS have a critical role to play in addressing the climate and biodiversity crises, they are not a 'silver-bullet' solution (Reise et al., 2022; Castelo et al., 2023). While 'approaches' may have been better choice, it is unlikely that efforts to rebrand the concept will be successful now that the NbS term is entrenched. To do so could also hinder progress on the development and implementation of NbS.

## MAKING SENSE OF A PLETHORA OF RELATED TERMS

There are a number of established terms and approaches that relate to the concept of NbS (Figure 5, Table 4). These terms and approaches stem from different disciplines, different sectoral contexts and different regions around the world (Sowińska-Świerkosz & García, 2022) but have the same general focus of working with nature for societal benefits (Nesshöver *et al.*, 2017). Many of the terms are not mutually exclusive, and in many cases a single action may qualify as several of the terms outlined below (Seddon *et al.*, 2021). Certain terms, such as ecological engineering and green infrastructure (GI) are targeted approaches (with explicit actions) for solving specific challenges, whereas other terms such as EbA, nature climate solutions (NCS) and ecosystem-based disaster risk reduction (EcoDRR) are defined based on intended outcomes and have a systematic approach to understanding the relationship between nature and society (Nesshöver *et al.*, 2017; Seddon *et al.*, 2021).

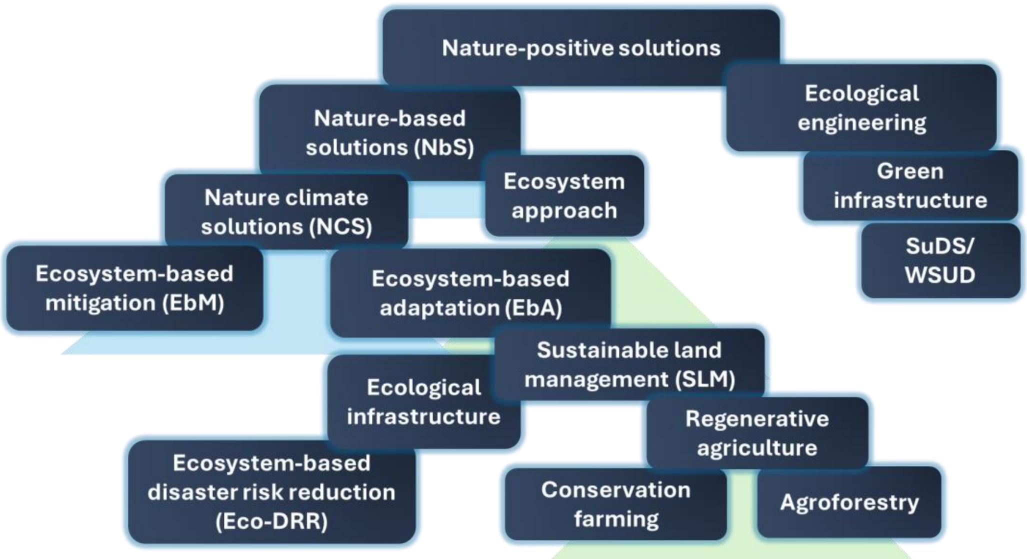



Figure 5. Some of the terms relating to NbS that are used in the literature and their approximate relationships to one another (Source: Authors).

Table 4. Terms that are encompassed by nature-based solutions. Source: Modified from Nesshöver *et al.* (2017); Seddon *et al.* (2021); Enu *et al.* (2023).

| Term | Definition / explanation | References |
|---|---|---|
| Ecological engineering | The design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both. | Mitsch & Jørgensen, 2003 |
| Ecosystem approach (EA) | The strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. | UNEP/CBD, 2000 |
| Ecosystem-based Adaptation (EbA) | The use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change. | CBD, 2009 |
| Ecosystem-based disaster risk reduction (EcoDRR) | The sustainable management, conservation and restoration of ecosystems to reduce disaster risk, with the aim of achieving sustainable and resilient development. | Estrella & Saalismaa, 2013 |
| Green/blue infrastructure (GI/GBI/BI) | A strategically planned and managed, spatially interconnected network of multi-functional natural, semi-natural and man-made green and blue features including agricultural land, green corridors, urban parks, forest reserves, wetlands, rivers, coastal and other aquatic ecosystems. | European Commission, 2013 |
| Sustainable urban drainage systems (SUDS), low impact development (LID), water-sensitive urban design (WSUD), best management practices (BMPs) | Various stormwater management approaches. SUDS are an integrated network of engineered vegetated areas and open spaces (i.e., green roofs, rain gardens, porous pavements, etc.) that offer a wide variety of benefits to people and wildlife. They are a complement to conventional sewer systems to minimize hydrological urbanisation impacts and increase resilience to extreme rainfall events in urban areas. | Ferrans *et al.*, 2022 |
| Integrated land mgmt (ILM), Sustainable land mgmt (SLM), integrated catchment mgmt (ICM). | Various approaches to managing whole landscapes sustainably to meet the needs of present and future generations, with participation by all stakeholders. | Rollason *et al.*, 2018; Thomas *et al.*, 2018 |
| Living shorelines | A suite of shoreline protection schemes that incorporate habitat restoration alone or in combination with some type of built infrastructure to provide coastal protective services to humans. | Smith *et al.*, 2020 |
| Ecosystem-based coastal defence | The creation and/or restoration of coastal ecosystems to minimise the impacts of sea-level rise, flooding and erosion. | Temmerman *et al.*, 2013 |
| Agroforestry | A land-use system in which trees or shrubs are grown in association with agricultural crops, pastures or livestock. | Torralba *et al.*, 2016 |
| Conservation agriculture (CA) | A farming system that promotes maintenance of permanent soil cover, minimum soil disturbance, and diversification of plant species. It enhances biodiversity and natural biological processes which contribute to increased water and nutrient use efficiency and improve and sustain crop production. | UN FAO |
| Forest and landscape restoration (FLR) | An ongoing process of regaining ecological functionality and enhancing human well-being across deforested or degraded forest landscapes. | IUCN |
| Climate change integrated land use strategies (CLICS) | Are climate-resilient conservation approaches that guide planning for ecosystem service corridors and protected areas that are resilient to climate change. | Hannah, Midgley & Millar, 2002 |
| Reduced emissions from deforestation and degradation (REDD+) | Reducing Emissions from Deforestation and forest Degradation, and fostering conservation, sustainable management of forests, and enhancement of forest carbon stocks in developing countries. | UNFCCC, 2014 |
| Natural climate solutions (NCS) or Nature-based Climate Solutions (NbCS) | Conservation and management actions that reduce greenhouse gas (GHG) emissions from ecosystems and harness their potential to store carbon. Note that the TNC does not include positive biodiversity outcomes as a requirement, only that there are no negative impacts. | Griscom *et al.*, 2017 |

The most general concept that encompasses most of these related terms is “nature-positive solutions”. Nature-positive implies that the actions will improve the condition of natural systems (and their biodiversity) within or downstream of the site of the action. Under this term, there are some approaches that are nature-positive without necessarily being nature-based. These are generally engineering measures that are designed to have a lower impact on the environment than conventional designs. They include the highly overlapping concepts of ecological engineering, GI and sustainable drainage systems (SuDS) and water-sensitive urban design (WSUD).

Nature-based solutions, on the other hand, include a wide range of biodiversity-positive approaches that are either implemented within natural, semi-natural or highly modified (agricultural) ecosystems (based in nature) or involve the creation of new ecosystems that include biotic elements (based on nature). Because this encompasses so many concepts, the term NbS (which has much wider application and deeper meaning than nature-positive solutions) is sometimes referred to as an umbrella term (Seddon *et al.*, 2021; Enu *et al.*, 2023).

Many actions could be included under multiple concepts. For example, mangrove restoration which reduces coastal flooding would qualify as EbA and also EcoDRR, and if the restoration also results in increased carbon storage, then it could also be classified as a natural climate solution (NCS; Seddon *et al.*, 2021). However, it should be noted that not all of the related concepts have the same stipulations or nest perfectly. For example, the concept of nature climate solutions is defined as having no negative impact on people or biodiversity, whereas NbS is defined as having positive impacts on both. This slightly changes the types of interventions that might be included under each term.

The large number of related concepts and terms (often used interchangeably) is the result of trying to capture the positive outcomes of working with nature in delivering both natural and social benefits in a way that is relatable to society who have grown accustomed to solving challenges with conventional engineering and technology. Therefore, these terms are in a way a form of advocacy or marketing in a rapidly growing field. As various climate and biodiversity strategies increase in popularity around the world so does the terminology being used to describe them. Terms keep changing or evolving because they become appropriated by different disciplines or because they need to be aligned with new thinking. This happens not just because people have different agendas, but also because people from different disciplines see and interpret words quite differently, especially those that are from non-traditionally environmentally minded sectors. Furthermore, terms are being invented and developed in different parts of the world, where people have different sensitivities and priorities. This has led to ambiguity and confusion around the NbS concept, and has led to contrasting narratives (Melanidis & Hagerman, 2022). Therefore, clear definitions and a typology, as well as best-practice guidelines are important for embracing NbS as part of a sustainability and net-zero carbon strategy (Seddon, 2022).

# VIABILITY AND COST-EFFECTIVENESS OF NBS

## MAKING THE CASE FOR INVESTING IN NBS

NbS are widely claimed to be both economically viable (i.e. benefits exceed costs) and cost-effective (i.e. achieves the result more cheaply than by other means). Part of the reason for this is the multifunctional nature of NbS interventions, which can deliver simultaneously on multiple objectives (e.g., adaptation, mitigation, risk reduction; Reguero et al., 2018; Reise et al., 2022) and provide a range of co-benefits compared to conventional options which tend to have a single focus.

The literature suggests that the potential benefits of NbS for addressing societal challenges, including climate adaptation and mitigation, are significant, with a high return on investment (ROI)[5]. However, concerns remain over the cost-effectiveness of NbS compared to engineered solutions and this is a key barrier to implementation at scale (Seddon *et al.*, 2020; Liu, Jay & Chen, 2021; Van Zanten *et al.*, 2023). Studies tend to focus on the economic viability of investing in NbS, which is to demonstrate positive net benefits or favourable return on investment (cost-benefit analysis or CBA), rather than cost-effectiveness, which compares the costs of alternative approaches to delivering a specified outcome (cost-effectiveness analysis or CEA).

Estimating cost-effectiveness involves estimating not only the costs and outcomes of the NbS interventions, but those of conventional alternatives. This is challenging when those alternatives involve complex engineering designs and costing. Therefore, rather than ensuring NbS are cost-effective, Reise *et al.* (2022) agree with the IUCN guidelines “that NbS projects should be appraised to the extent possible to ensure economic viability”.

Assessing economic viability of multifunctional NbS is nevertheless challenging:

- Many of the co-benefits are not adequately accounted for and/or the full scale of benefits are not immediately evident (Van Zanten *et al.*, 2023);
- Trade-offs exist between different stakeholder groups with different preferences, and these are often not well quantified or captured (e.g., opportunity costs);
- Quantifying changes in ecosystem services over time is difficult, particularly when considering the uncertainties in future conditions; and
- Attribution of a positive change or benefit to a specific activity or intervention is difficult to do.

NbS tend to take longer to establish and generate benefits than engineered solutions, with their efficacy varying depending on the level of intensity and frequency of hazards (Seddon, 2022). Current frameworks do not always consider the long term economic benefits that they provide because of the difficulty in quantifying changes in ecosystem service provisioning over time (Seddon *et al.*, 2020; Reise *et al.*, 2022). Furthermore, estimating benefits from NbS is difficult relative to those of engineered infrastructure partly because they may be relatively far-reaching in scale and the demands of beneficiaries may also vary spatially (Van Zanten *et al.*, 2023). In addition, accounting for the effect of climate change on the flow of benefits is particularly challenging

[5] ROI should be greater than 1. For example if it is 2, then for every $1 invested, the benefits are $2. It is measured using the present value of the costs and benefits over a defined period of time.

(Seddon *et al.*, 2020). There are also challenges in capturing local level variability in implementation and management costs (Griscom *et al.*, 2017).

Because of the difficulties in gathering empirical evidence under the long timeframes involved, studies rely heavily on modelling and projection. With the significant improvements in these techniques over the last decade, the many feasibility studies that have been carried out are providing an increasingly strong case for NbS. For example:

- Investing US$1.8 trillion globally in early warning systems, climate-resilient infrastructure, improved dryland agriculture crop production, global mangrove protection, and investments in making water resources more resilient from 2020 to 2030 could generate US$7.1 trillion in total net benefits (GCA, 2019);
- In the US Gulf of Mexico coast, NbA measures were found to the among the most cost-effective options, averting 36.6% of total climate risk with an average benefit to cost ratio of 3.7 to 4.9 (Reguero et al., 2018); and
- The global value of the coastal flood protection services of mangroves (avoided damages to people and property due to the presence of mangroves) has been estimated at between US$65 billion and US$82 billion annually (Losada *et al.*, 2018; Menéndez *et al.*, 2020).

While much of this evidence stems from the Global North, there is evidence emerging from the Global South too, that successfully makes the economic case for investing in NbS (see TNC, 2015a, 2019; Turpie *et al.*, 2017; Mulligan *et al.*, 2020; WWF, 2021; Enu *et al.*, 2023; Van Zanten *et al.*, 2023; Daigneault, Brown & Gawith, 2016). Furthermore, the benefits quantified in these assessments are often underestimated as they tend to consider only climate and/or disaster risk reduction benefits and disregard other ecosystem services, which in many instances provide significant additional benefits in the form of tourism and recreation, provisioning of food and raw materials, and health (Van Zanten *et al.*, 2023).

Most studies have focused on the economic feasibility or viability of implementing NbS, to make the case for investment. These studies have identified opportunities for NbS to solve a range of societal challenges, they estimate the costs of the interventions required, and the estimate the benefits relative to a no-intervention scenario (or business-as-usual).

Fewer studies have considered cost-effectiveness relative to more conventional solutions, perhaps partly because of the addition steps required to estimate the conventional costing, which may require engineering input, but possibly also because it may entail ignoring co-benefits that are regarded as an important aspect of NbS. Because of the lack of evidence on cost-effectiveness, the UNEA did not explicitly include cost-effectiveness in their definition of NbS. Assessing cost-effectiveness entails explicit consideration of how a societal challenge that this being addressed through an NbS intervention would be addressed conventionally (see Table 2), and for that conventional approach to be costed. Cost effectiveness analysis requires costs to be expressed relative to a measure of a specified output, such as cost per unit of water supplied, or cost per degree of cooling achieved.

There is still a need to better understand how the effectiveness of NbS interventions might be impacted by potential climate change scenarios. For example, if natural habitats such as coral reefs will be unable to survive beyond some level of warming, then NbS relating to this type of ecosystem may become ineffective. Adopting a common approach to quantifying and valuing NbS benefits has been highlighted as one of the key action points towards decreasing the barriers for donor funding support for NbS. Such an approach would also significantly contribute towards addressing the divergent views about the effectiveness of NbS as per the UNEA and other definitions.

## RESTORATION, MANAGEMENT AND PROTECTION OF NATURAL ECOSYSTEMS

NbS interventions of this type involve conservation measures to restore, sustainably manage and/or protect natural or semi-natural areas that provide valuable ecosystem services, typically regulating services. Employing nature to reduce flood risk and improve water quantity and quality requires understanding the many physical processes that depend on the interaction between water, sediments and vegetation (Van Zanten *et al.*, 2023). As a result of these complex interactions, the impacts tend to be highly site specific and difficult to quantify. However, with the improvement in process modelling that has occurred over the last decade, there has been a substantial increase in the evidence of the contribution of NbS for climate resilience.

In coastal settings, there is evidence of significant benefits, economic viability and cost-effectiveness of conservation interventions:

- The protection of mangroves in Jamaica was found to have an average ***risk reduction benefit*** against tropical cyclones to the value of US$2500 per hectare (Van Zanten *et al.*, 2023). Additional benefits included carbon storage and sequestration with an estimated value of US$180 million per year, and nearshore fisheries with a total value of US$2.7 million per year (Van Zanten *et al.*, 2023).
- In the US Gulf Coast of Mexico, coastal NbA options, such as wetland and oyster reef restoration have been estimated to have average ***benefit to cost ratios*** above 3.5 (Reguero *et al.*, 2018).
- A global assessment by Narayan *et al.*, (2016) provides evidence for the ***cost-effectiveness*** of restoration and protection of coral reefs, mangroves and dunes for coastal protection (i.e., a reduction in flood risk), with NbS being two to five times cheaper than conventional breakwater infrastructure (Box 1).

Box 1: Protection and restoration of coastal habitats in the Gulf of Mexico. Source: Narayan *et al.* (2016); Reguero *et al.* (2018).

**Ecosystem type:** Coastal
**Sectoral outcome:** Reduce coastal erosion and flooding.
**Co-benefits:** Climate regulation, breeding and nursery areas for fish, tourism & recreation

Narayan *et al.*, (2016) undertook a global assessment of the cost and benefits of NbS for coastal protection and NbS' effectiveness in reducing wave height in coastal habitats. They particularly look at the effectiveness of mangroves, salt mars**h**, coral reefs and seagrass/kelp beds for wave height reduction. They find that coral reefs and saltmarsh have the highest overall potential. Saltmarsh and mangroves can be two to five times cheaper than submerged breakwaters which reduce wave heights up to half a metre. Additionally, such habitats provide other benefits that engineered solutions do not render, such as breeding grounds for fish and areas with recreational benefits for local residents (Narayan *et al.*, 2016).

Another study which focused on coastal protection across the Gulf of Mexico coast, United States, NbS, such as reef restoration, yielded higher cost benefit ratios compared to engineered solutions, including seawall construction (Reguero *et al.*, 2018). NbS had an average benefit-cost ratio above 3.5, with wetland restoration at risk reduction priority areas (ROI of 8.7) and oyster reef restoration (ROI of 8.7) being particularly cost-effective. As to the engineered solutions, while sandbags were comparatively cost effective (ROI of 10), the other engineered solutions, such as levees and home elevation had low ROI's (below 1). Given that climate change and requirements for coastal adaptation will intensify in the future, NbS provide an attractive option in coastal areas.

In inland ecosystem settings, restoration and protection of catchment landscapes, wetlands and riparian areas can significantly improve water security (i.e., water supply, water quality and flood attenuation), and can be both economically viable and cost-effective compared to engineering options:

- An economic valuation of watershed management practices for erosion and sediment reduction in the Kali Gandaki Watershed in Nepal found that investments in conservation interventions such as reclamation/rehabilitation of degraded land (forest and grasslands), and soil and water conservation practices could secure significant water supply benefits. The US$3 million portfolio yielded a ***benefit-cost ratio*** of 2.28 (Van Zanten *et al.*, 2023).
- In the Mazowe Catchment in Zimbabwe, the impact of conservation and sustainable landscape management practices on ecosystem service values (erosion control and sediment retention, flow regulation, carbon storage, harvested wild resources, crop production) were found to be economically feasible with these actions producing ***benefits that outweigh their costs*** with an ROI of 1.7 over the Mazowe Catchment as a whole (Box 2; Turpie *et al.*, 2022).
- In Fiji, planting of riparian buffers, reforestation of upper catchment areas, and planting floodplain vegetation to improve flood amelioration services was found to be economically feasible with resulting ***benefit-cost ratios*** ranging from 2.8 (under current climate) to 21.6 (under severe climate change; Box 4; Daigneault *et al.*, 2016).
- In the catchment areas that supply water to the City of Cape Town, restoration in the form of clearing of invasive alien plants was found to be the most ***cost-effective*** option when compared to other conventional water supply approaches such as ground water and desalination (Stafford *et al.*, 2019; Turpie *et al.*, 2019; Box 3).

Box 2: Benefits of implementing sustainable land management and conservation-focused interventions in the Mazowe Catchment, Zimbabwe. Source: Turpie *et al.*, 2022.

**Ecosystem type:** Terrestrial and freshwater (catchments)
**Sectoral outcome:** Improve water security.
**Co-benefits:** Biodiversity, food security, tourism and recreation, carbon storage.

In the highly degraded Mazowe Catchment, the impact of conservation actions - climate smart agriculture, restoration of riparian buffers that have been lost to cultivation, the passive restoration of degraded natural habitats, management of grazing and resource harvesting pressures, and the improvement of community conservation areas - on ecosystem service values was compared to a business-as-usual (BAU) scenario in which further catchment degradation occurs. The results showed that investing in these conservation actions could collectively increase groundwater recharge by 4.5%, worth around US$11.8 million per year in terms of water supply, and improved erosion and sedimentation control arising from these interventions could reduce erosion across the catchment by 48% and sediment export to dams by 62% relative to BAU resulting in cost savings of US$10.2 million per year in avoided sediment control costs in reservoirs. Erosion from communal farmland would be roughly halved, bringing erosion rates closer to tolerance levels. Furthermore, the interventions would increase the value of wild resource harvesting relative to BAU, sequester carbon worth at least US$13.5 million per year, and increase small-scale crop production by 9.5% relative to BAU. Overall, well-implemented restoration and conservation interventions could produce benefits that outweigh their costs with an ROI of 1.7 over the Mazowe Catchment as a whole.

Box 3: Assessing the cost-effectiveness of ecological infrastructure restoration in Cape Town, South Africa. Source: Stafford *et al.*, 2019; Turpie *et al.*, 2019.

**Ecosystem type:** Terrestrial and freshwater (catchments)
**Sectoral outcome:** Improve water supply (quantity)
**Co-benefits:** Biodiversity, wildfire risk reduction, tourism and recreation

Invasive alien plants (IAPs) have spread through the catchment areas which supply Cape Town and nearby towns with water. IAP invasion has led to increased levels of wetland and riparian area degradation resulting in water and biodiversity losses. Efforts have been made to clear IAPs from priority areas to improve catchment health and increase water supply. But continuous spread of IAPs does not only influence water availability but also affects the probability of wildfires. Better controlling of IAPs therefore could have positive implications for infrastructure, livelihoods, erosion and sedimentation as well as economic opportunities.

Sub-catchments were prioritised for IAP clearing based on the ROI, which considered the amount of water (in $m^3$) that could be generated per Rand invested in IAP removal and follow-up over 30 years (TNC, 2019). Without intervention, water loss from IAPs is expected to double within the next 30 years. Catchment restoration in the seven priority sub-catchments was estimated to deliver an average unit reference value (URV) of R1.2 per $m^3$ (including water treatment cost) and an additional 55.6 $Mm^3$ of water per year (TNC, 2019). In comparison, groundwater exploration was estimated to yield an additional 36.5 $Mm^3$ of water per year at a URV of R6.7 per $m^3$; water reuse could provide 32.9 $Mm^3$ of additional water per year at a URV of R11.1 per $m^3$; and desalination could add another 55 Mm3 per year at a URV of R14.9 per m3. While IAPs and desalination have the potential to provide the same amount of water per year, IAP removal would be able to do so at a fraction of the cost. Opposed to grey infrastructure options, catchment restoration provides water supply improvements from the start and does not require replacements but produces water yield gains in perpetuity if IAP infested areas are maintained after clearance. (Stafford et al., 2019).

- In South Africa's semi-arid Namaqualand region, it was estimated that undertaking wetland restoration as a means of securing the carrying capacity of land for pastoralist communities as a means to improve resilience under projected future climate conditions would be more ***cost-effective*** than the conventional alternatives of drilling boreholes and using supplemental feed for livestock, even though the latter alternatives are more likely to be implemented further into the future (Black, Turpie & Rao, 2016).

In urban settings, the restoration and protection of natural areas and riparian buffers can provide valuable services including sediment trapping, water infiltration, and/or water quality amelioration as well as for amenity.  Some examples of economically viable and cost-effective interventions include:

- In Colombo, Sri Lanka, an economic analysis in the metro was used to advocate for the support of wetland conservation and management as natural flood retention areas (Van Zanten *et al.*, 2023). The natural urban wetlands complement the grey stormwater infrastructure by slowing down infiltration and filtering stormwater into the ground, thereby decreasing the volume of water that needs to move through the conventional grey infrastructure (Browder *et al.*, 2019). Most scenarios had a ***positive net present value***, and this value increased with increasing area under protection.

Box 4: Flood alleviation in Fiji. Source: Daigneault *et al.* (2016).

**Ecosystem type:** Terrestrial and freshwater (catchments)
**Sectoral outcome:** Reducing flood risk.
**Co-benefits:** Climate regulation, breeding and nursery areas for fish, tourism & recreation

The potential of ecosystem-based adaptation for flood alleviation (planting of riparian buffers, reforestation of upper catchment areas, and planting floodplain vegetation) was assessed in two river catchments located in Fiji (Daigneault et al., 2016). The analysis found that NbS were more cost-effective compared to engineered infrastructures using hydrological models and simulating flood damages (Daigneault et al., 2016). Three engineering options were evaluated: riverbank reinforcement, river dredging, and elevating houses. The most economically feasible measure was planting of riparian buffer vegetation, which resulted in benefit-cost ratios ranging from 2.8 (under current climate) to 21.6 (under severe climate change). The most advantageous approach overall was upland reforestation, with net present values ranging from 12.7 to 101.8 million Fijian dollars (equivalent to US$6.1-48.9 million) (Daigneault et al., 2016). Among the engineered infrastructure options, river dredging was deemed to offer the most significant benefits. However, the associated costs were relatively high compared to the benefits, and the advantages were estimated to be only realised in a portion of the downstream catchment.

## MANAGEMENT OF CULTIVATED ECOSYSTEMS

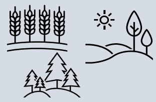
NbS interventions in cultivated systems aim to reduce environmental damages while also increasing productivity. This has been shown to be particularly effective in the Global South, where people are heavily reliant on agriculture and there is large scope for improved management. There is evidence to suggest that NbS are cost-effective interventions in managed ecosystems in that they can enhance resilience in agriculture and food production, while enhancing biodiversity and mitigating climate change (Miralles-Wilhelm & Iseman, 2021).

There has been a strong emphasis on introducing agroforestry in areas where agriculture contributes to deforestation. A meta-analysis of 53 publications on the effects of agroforestry found that there was an overall positive effect of agroforestry over conventional agriculture and forestry land use (effect size = 0.454, $p<0.01$; Torralba *et al.*, 2016). Furthermore, the same study found that both silvo-pastoral and silvo-arable systems increase the provision of ecosystem services as well as biodiversity, especially when compared with plantation forestry land (Torralba *et al.*, 2016).

The two studies highlighted in Box 5 and

Box 6 show how the investment in long-term conservation initiatives and working with local farmers can generate positive returns. In the Upper Tana watershed in Kenya, investing in six interventions - planting riparian vegetation, introducing agroforestry, terracing hills, reforesting, planting grass strips in farmland, and mitigating against road erosion – generated a return on investment of 2.15 when considering the benefits of improved agricultural yields, reduced water treatment costs, and increased hydropower production (Box 5, TNC, 2015).

Box 5. Investing in nature-based solutions in the Upper Tana watershed, Kenya. Source: TNC (2015)

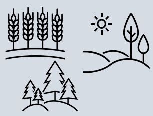


**Ecosystem type:** Agricultural (and terrestrial and freshwater catchments)
**Sectoral outcome:** Improving water security.
**Co-benefits:** Climate regulation, improved agricultural yields.

The Upper Tana-Nairobi Water Fund was set up to support long-term conservation initiatives in the Upper Tana watershed to increase water security for the residents of Nairobi. Forest degradation on steep hills, mostly due to damaging farming practices, has led to high levels of water runoff and sedimentation. Green infrastructure interventions can improve ecosystem health in areas where runoff water can be stored and filtered and be cheaper than engineered options such as the construction of water reservoirs and treatment plants. Additionally, sustainable management practices upstream can improve water quality and quantity downstream.

Six interventions were modelled and evaluated: planting riparian vegetation, introducing agroforestry, terracing hills, reforesting, planting grass strips in farmland, and mitigating against road erosion (TNC, 2015). First it was determined where to spatially target the different investment options (using Resource Investment Optimization System, RIOS), then the benefits of the investments were assessed (using Soil and Water Assessment Tool, SWAT) and finally the economic benefits were calculated and the return on investment (ROI) of the interventions was determined. Initial ROI calculations for the Upper Tana-Nairobi Water Fund showed that a US$10 million investment, disbursed at US$1 million per year over 10 years, could return US$21.5 million in economic benefits over 30 years – a ROI of 2.15 (TNC, 2015). Benefits include increased agricultural yields, reduced water treatment costs, and increased hydropower production. Benefits were calculated over a time horizon of 30 years to ensure that full impact of interventions can be realised.

Box 6. Nature-based solutions for water security in Sierra Leone. Source: Raes *et al.* (2021)



**Ecosystem type:** Agricultural (and terrestrial and freshwater catchments)
**Sectoral outcome:** Improving water security.
**Co-benefits:** Climate regulation, biodiversity gains, improved agricultural yields.

The city of Freetown situated on the Western Area Peninsula (WAP) in Sierra Leone is facing growing water security issues. Urban and agricultural expansion has been the strongest driver of forest loss in the WAP leading to degradation of the ecological infrastructure which supports the water supply to around two million people (Raes et al., 2021). Forests have been cleared for farming, fuelwood harvesting, charcoal production, logging and stone quarrying.

Modelling was undertaken to determine the impact of various alternative land management decisions on water quality and quantity as well as urban flooding and sediment retention (Raes et al., 2021). An economic study was conducted to determine the impacts of making no significant new investments in forest protection or restoration, assuming that urban and agricultural expansion continues (a Business-as-Usual Scenario), and a Conservation Scenario which envisions significant investments in decreasing deforestation through improved management of the catchment area, active planting of trees, assisted natural forest regeneration, passive forest regeneration, agroforestry, fencing and introduction of riparian buffer zones. Over a 30-year period, the conservation scenario ROI was estimated to be 2.7. It was calculated that reducing the amount of sediment entering the rivers of the Western Area Peninsula and ultimately the reservoirs through conservation and restoration activities would be ten times more expensive if mechanical dredging was used to remove dredge spoil off site. On top of this, reducing sedimentation through NbS would increase the lifespan of the reservoirs by between 60%-67%.

## ENGINEERED ECOSYSTEMS

It has been found that NbS are cost-effective in protecting communities against less extreme hazards (Daigneault *et al.*, 2016; Seddon *et al.*, 2020), while hybrid solutions involving a combination of both engineered and nature-based designs tend to be more effective for high-intensity hazards (Seddon, 2022). This is particularly the case in urban and coastal environments. Some examples are:

- An assessment of nature-based infrastructure to mitigate flooding and heat risk in the City of Tshwane, South Africa showed that NbS can effectively reduce the cost of stormwater treatment and cooling for buildings, and at the same time improve the urban green environment (and thus the amenity value) for residents (WWF, 2021). The analysis showed that investment in green roofs and street trees was economically viable with green roofs having a ***benefit-cost ratio*** of 1.21 and street trees a benefit-to-cost ratio of 31.17 (WWF, 2021).
- In Dar es Salaam, a mix of catchment forest restoration, riparian rehabilitation and detention basins designed to mitigate flooding were shown to have a positive **return on investment**. The costs of these interventions were estimated to be similar to the grey infrastructure alternative (i.e. just as ***cost-effective***), but the NbS had added biodiversity and recreational benefits (Box 7).

Box 7. Preventing urban flooding in Dar es Salaam through hybrid NbS. Source: Turpie *et al.*, 2017a; De Risi *et al.*, 2018.

**Ecosystem type:** Urban
**Sectoral outcome:** Reducing flood risk.
**Co-benefits:** Climate regulation, biodiversity gains, improved agricultural yields.

Flood risk in the Msimbazi catchment in Tanzania's capital city of Dar es Salaam is a growing concern. Unplanned residential housing in floodplains and riverbanks, a densely populated catchment area, and high levels of deforestation due to agricultural activities and charcoal productions have led to increased risk and exposure to flooding. The catchment has been experiencing increased stormwater runoff, reduced water quality, and reduced capacity to regulate flows (Turpie *et al.*, 2017a). The river water is highly polluted and, in some areas, not safe for human contact.

A mix of green-grey interventions (hybrid approaches) to alleviate flooding in Dar es Salaam were analysed to assess their potential to reduce exposure to flooding, reduce flood risk, or a combination of risk and exposure reduction (Turpie *et al.*, 2017a). The following measures were included in the study:

- Riparian setbacks in the flood prone areas;
- Green urban development measures (GUD);
- GUD measures + riparian setbacks in the flood prone areas;
- GUD measures + additional detention basin(s); and
- GUD measures + detention basin(s) + riparian setbacks in the flood prone area.

Catchment rehabilitation measures yielded the highest rates of return, suggesting that funding should be secured for interventions that attenuate flows and improve drainage. Adding a storage basin added the least amount of value. The ROI of the different interventions was between 0.7 and 1.3 over 10 years and between 1.3 and 2.5 over a 50-year time horizon. Riparian setbacks in flood prone areas (measure 1) yielded the highest ROI, while green urban development measures in combination with detention basin(s) and riparian setback in the flood prone areas yielded the lowest ROI. Engineered solutions to protect the city against future flood events (through lining of the main drainage channel) were costed at US$29 million. These costs are similar to the main green urban development intervention suggested in the study – rehabilitation and enhancement of riparian and catchment areas. However, grey infrastructure would have no additional positive impact on water quality.

- In Durban, South Africa, various combinations of NbS interventions (maintaining natural open space areas, riparian buffers, constructed wetlands, green roofs) and green engineering measures (porous paving, detention basins) were tested in terms of their efficacy and cost-effectiveness for mitigating flooding and water quality issues. NbS were ***cost-effective*** compared to engineering measures, some of which were extremely costly to implement at scale (Box 8).

Box 8. Evaluating the potential returns to investing in Green Urban Development in Durban (Turpie *et al.*, 2017c)

**Ecosystem type:** Urban
**Sectoral outcome:** Flood and water quality amelioration, sediment control
**Co-benefits:** Climate regulation, biodiversity gains, amenity value.

A scenario-based approach was used to explore the potential costs and benefits of undertaking a green urban development approach to address flooding, water quality and biodiversity loss in Durban, and to explore the potential trade-offs between engineered interventions and the conservation of natural open space areas.

Flows and water quality in the central Umhlatuzana - Umbilo catchment were modelled under a series of hypothetical back-casted scenarios in which the development of the area had involved different combinations and extents of GUD measures including better sanitation, stormwater management (including infiltration trenches, subsurface soakaways, permeable paving, green roofs, detention basins, and treatment wetlands) and conservation measures (protection of natural open space areas and riparian buffers).

The scenarios were evaluated in terms of their implications for aquatic ecosystem health as well as the infrastructure costs and the losses in property value, tourism and fishery values that would have been avoided under these alternative scenarios. There was relatively little backlog in sanitation, but addressing this issue and engaging in waste water recycling made a significant difference in water quality in the catchment. With or without this improvement, green engineering interventions were found to have a significant effect.

The measures that were specifically designed for stormwater management – source controls (infiltration trenches, soakaways, permeable paving and green roofs) and detention basins – reduced flood peaks by about 10%, and 35%, respectively, and also contributed to improved water quality. Under improved sanitation conditions, treatment wetlands were very effective at improving water quality in the catchment. However, the large-scale application of some of the low-impact stormwater management measures is still extremely costly, even when accounting for economies of scale. Of all the source control measures that could be feasibly implemented, only detention basins could be justified in terms of their cost savings. It is feasible that the rest will become more affordable in time, as necessity will continue to drive this kind of innovation, and bringing these requirements into law in Durban will also drive this process.

The study also analysed the impacts of a planning scheme which allows greater retention of natural green open spaces in the city to meet conservation targets. This strategy had a significant impact on flooding, by virtue of the fact that the hardened area was reduced. It also had a moderate impact on water quality. The net benefits of this strategy far outweighed any other. Smart planning with green open space areas coupled with the other interventions creates the greenest city, in terms of meeting water quality and biodiversity conservation goals, and is an economically justifiable strategy in terms of overall costs and benefit.

- In the Seychelles, hybrid coral reef restoration (or the blue barrier approach) has been identified for risk reduction (Van Zanten *et al.*, 2023). Employing this approach does not only have the benefit of avoided infrastructure damage costs but also leads to tourism and recreation benefits as well as artisanal fishing benefits. The results of the economic analysis supported the idea of combining coral restoration with engineered options to achieve implementation at scale and to address both environmental and resilience issues (Van Zanten *et al.*, 2023). The risk reduction benefits included an additional 28% wave reduction with the Blue Barrier as well as a reduction in longshore sediment transport rates of up to 74% during a 50-year average recurrence interval (ARI) event (Van Zanten *et al.*, 2023).

- In the coastal City of Nacala in Mozambique, the use of nature-based solutions for urban flood risk management were assessed. The study area included 13 catchment areas in the city focusing on the communities' surrounding gullies, erosion channels, and unused lands (World Bank, 2020). The potential costs and benefits of revegetation of land in combination with alternative GI measures, which included retention ponds, improved drainage systems, toe protection of gullies, and small-scale revegetation were assessed using a ***cost-benefit analysis*** (World Bank, 2020). The results show that both the economic benefits and the financial benefits have a positive net result, with the financial benefits reaching around US$7.9 million per year and the economic benefits resulting in around US$17 million per year at $0 carbon price. The annual cost of damages associated with erosion were just under US$3 million per year without the project and just under US$300 000 per year with the project, a saving of 90%, and the agricultural benefit associated with green urban gardening was $6000 per hectare per year (World Bank, 2020).

# BARRIERS AND CHALLENGES TO ADOPTING AND IMPLEMENTING NBS

## ENVIRONMENTAL CHALLENGES

There is a rising criticism of NbS due to activities that are carried out in the name of NbS without meeting its environmental criteria or standards, and resulting in negative impacts on biodiversity and ecosystem services. This generally arises through ignorance of matters relating to biodiversity and the ecological context, with negative consequences being entirely unintentional. Such situations arise as a result of an absence or lack of enforcement of requirements to evaluate all impacts of projects using best practice methods and ensure the relevant safeguards are in place.

The main issue in this regard is relates to the planting of trees as a means of climate change mitigation. Deforestation and forest degradation have made a significant contribution to atmospheric $CO_2$, and reversing this trend can help to mitigate climate change through $CO_2$ sequestration. According to the IPCC, restoring forest cover by 350 million hectares is required, along with other measures, to limit global warming to 1.5 degrees Celsius. The Bonn Challenge was launched in 2011 with the goal of restoring 150 million hectares of degraded and deforested landscapes by 2020 and 350 million hectares by 2030. Countries committed to contributing to meeting these goals in several ways, including creating plantations (45%), and expanding agroforestry (21%) and restoring natural forests (34%). Plantations are globally the most popular option for restoration as they turn trees into profitable enterprises (Lewis *et al.*, 2019). However, plantations are not a substitute for natural forests.

Even though plantations fall under the FAO's definition of forests[6], they are cultivated systems rather than natural ecosystems, and provide no biodiversity benefits (Lewis *et al.*, 2019), and on the contrary, can be deeply damaging to biodiversity (Bond *et al.*, 2019). Exotic tree plantations are effectively 'biological deserts', and their establishment has no benefit to nature or biodiversity. On the contrary, their establishment erases opportunities to restore natural forest and often increases the fragmentation and isolation of natural forest habitats. Commercial plantations often comprise non-native species which use more water than native species and which can become invasive in surrounding areas, as has happened extensively in South Africa.

Furthermore, monoculture plantations do not have particularly high benefits in term of climate change mitigation (Lewis *et al.*, 2019). They sequester a lot of carbon in the short term but do not maximise carbon storage as they are regularly harvested and more vulnerable to climate change and diseases than natural forests. Promoting climate stabilisation through plantations of commercial trees would therefore bring fewer benefits compared to returning degraded lands back to natural forests and protecting them (Lewis *et al.*, 2019). Natural regeneration should be the focus for degraded forests and agroforestry should also be considered in working landscapes, over plantations (Lewis *et al.*, 2019).

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6 Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use.

When planning NbS, it is important to distinguish between reforestation and afforestation. Reforestation refers to planting trees on land that historically had forest, while afforestation refers to planting trees on land where trees historically did not occur. Grasslands, savannas and open-canopy woodlands (grassy biomes) have previously been misidentified as providing opportunities for afforestation (Veldman *et al.*, 2015). While the Bonn Challenge specifies the reforestation of former forest areas, there has also been an increasing tendency for countries to promote tree planting across any landscape areas in the name of restoration and climate change mitigation. Thus one sees trees being planted in grasslands and even wetlands, effectively degrading or further degrading those habitats. A number of climate change mitigation strategies, both from governments as well as from the private sector, are focusing on these misinformed "restoration activities" and neglect the impact that better protection and land management could have (Cook-Patton *et al.*, 2021). China's reforestation policy demonstrates that tree planting needs to be carefully planned and implemented in order to avoid unintended consequences (see Box 9).

Box 9. China's reforestation policy highlighting that tree planting needs to be carefully planned and implemented.

Tree planting has been presented as the silver-bullet to climate change mitigation. However, trade-offs and potential adverse impacts on ecosystems need to be considered. Highlighting tree planting as the optimal solution distracts from the need to protect and reconnect ecosystems across landscapes and seascapes. While tree planting can achieve numerous benefits, such as carbon sequestration, water quality amelioration, and reducing urban heat, and help improve ecological and human well-being, it should not overshadow actions with greater potential to address environmental issues, such as reducing deforestation and greenhouse gas emissions through other more radical approaches (Hua *et al.*, 2018; Holl & Brancalion, 2020; Seymour, 2020).

China's reforestation policy increased tree cover growth by 32%, however this was achieved through the conversion of cropland to tree plantations, and mostly through planting non-native tree species. The tree planting initiative reduced overall cropland availability. As a result, small scale farmers moved their farmland into adjacent areas leading to a further decline in natural forest cover (by 6.6%; Hua et al., 2018). Ultimately, the reforestation policy decreased native forests, including forests that could have regenerated naturally on land freed up from agriculture (Jordan, 2020).

Rather than focusing on tree planting, efforts should be put into the protection of remaining intact forest systems through better law enforcement, protection indigenous people's land rights, and providing incentives for conservation (Holl & Brancalion, 2020). China's policies should have better protected remaining natural forests and improved restoration of native forest landscapes (Hua *et al.*, 2018).

## TECHNOLOGICAL CHALLENGES

Technological and data challenges pertain to the location and design of NbS, which need to be based on accurate data and sound scientific assessment. The location of NbS needs to be informed by information on the existing condition as well as how benefit flows will change after implementation. The design of the action, for example how to restore a wetland or how to build a new one, require detailed information on the site of action, and technological know-how, such as on the available technologies to stem erosion or to aerate an artificial wetland to increase its capacity to remove nutrients. In cultivated contexts, technologies may include what varieties to plant. The main technological challenges therefore relate to the availability of data and evidence or proof of concept upon which to base designs.

For example accurate land cover and ecosystem maps are require to ensure that interventions are appropriate and effective (Veldman *et al.*, 2015). Since a large part of NbS focuses on restoration of degraded ecosystems, the assessment of condition is particularly important. However, data collection and analysis for condition assessment is time consuming and labour intensive, and the lack of allocation of funding for this purpose can compromise decision-making (see Box 10). Challenges in available data sources need to be addressed. Robust monitoring and evaluation systems need to be put in place to assess the environmental impacts of NbS. Depending on the NbS which are implemented, changes in biodiversity, carbon storage and sequestration levels or water quality need to be measured regularly. Monitoring and evaluation frameworks which generate reliable data for informed decision-making need to be created.

Box 10. Data-related issues with evaluating NbS costs, benefits and cost-effectiveness.

The uncertainty and lack of information about the potential benefits that NbS could achieve have been highlighted as barriers to NbS uptake by policy- and decision-makers. This lack of comprehensive information and data as well as conflicting information has also been demonstrated by several case studies in Van Zanten et al. (2023).

The case study "*Mangrove Restoration for Resilience*" showcases a cost-benefit analysis of mangrove forest restoration in Indonesia. However, valuation of cultural services derived from mangrove forests is limited by the lack of detailed tourism data. If more data on the recreational use of mangrove areas and data on actual visitor numbers were available, the cost-benefit analysis could have been more accurate. However, such data entails survey data collection which would require additional resources.

The case study "*Wetland Conservation in Colombo*" looks at the protection of inland wetlands to reduce flooding, erosion and extreme heat in Sri Lanka. It was found that the modelling of wetlands for flood risk reduction could have been improved through better exposure and vulnerability data. While a flood risk assessment model was done for the whole project, it did not specifically look at the benefits that urban wetlands could provide for flood mitigation due to the lack of data.

The case study on "*Coastal resilience in emergency recovery*" shows a cost benefit analysis to assess the feasibility of NbS, including mangrove forests and sandy shores and dunes, for coastal protection in Beira, Mozambique. A cost-benefit analysis was done for four different coastal sections assessing three design alternatives. A multicriteria analysis and the cost-benefit analysis were conducted separately, presenting different results and included in the same report.

Implementing NbS and collecting relevant monitoring and evaluation data requires technological expertise and specialised conservation and biodiversity knowledge. Developing countries trying to implement NbS may face capacity constraints in terms of scientific research as well as monitoring and evaluation structures ensuring the programme's longer time success. Technologies are not ready-to-use yet and require specialised training for design, implementation and permit authorisation (Egusquiza, Cortese & Perfido, 2019). Designers tend to be more familiar with traditional engineered solutions from a technical perspective (Egusquiza *et al.*, 2019). Additionally, knowledge transfer between the scientific community, policymakers and planners is often inadequate.

There still is a lack of established protocol for design, implementation and maintenance of NbS (Egusquiza *et al.*, 2019). The lack of clear methodologies of tracking project impacts poses a barrier to developing a robust pipeline of NbS investments and makes it difficult to compare them to other investment options (Swann *et al.*, 2021). Researchers are still building the empirical evidence of NbS benefits (Nelson et al., 2020). Awareness and uptake of NbS across Africa has been limited; there has been limited documentation of research on NbS on the African continent; and research collaborations are lacking (Nyika & Dinka, 2022). A better integration and exchange of expert knowledge from a wider range of disciplines, including engineering, architecture, and urban planning, would increase awareness about NbS interventions (Kabisch *et al.*, 2016). Better communicating and highlighting best practice examples could also increase awareness (Kabisch *et al.*, 2016).

## SOCIAL CHALLENGES

The implementation of NbS projects is often challenging due to a range of social and developmental factors, with many projects having disappointing outcomes as a result. Such challenges include poverty, gender inequality, low levels of education, literacy and capacity, poor access to water and sanitation, limited marketability and/or poor market access; and poor access to inputs, services, and technical knowledge. Many rural communities live in poverty and are highly dependent on natural resources, with women being particularly vulnerable in this regard. This limits their ability to afford the investments that are often required in the NbS activities that are being proposed. Another prevalent issue in Africa is informal land tenure which creates a lack of incentive to implement NbS. Weak land tenure also influences access to markets and credit.

Social challenges around the implementation of NbS are characterised by difficulties in gaining the cooperation and support of communities that are directly affected by or that would have to implement the proposed changes in management practices and a slow rate of uptake of these changes, irrespective of how well they are designed and how well they can be justified in terms of their societal welfare. Such challenges often boil down to the following (Turpie *et al.*, 2024):

- Inadequate approaches to introducing the proposed measures in a community area;
- Proposed measures not including sufficient consideration to mitigate and/or offset/compensate any residual negative consequences for local communities;
- Proposed measures not taking into account the cultural norms of an area, including the gender differences in these and specific challenges of women, youth and marginalised groups;
- Lack of human capacity in terms of literacy, education and knowledge to appreciate and undertake the interventions; and
- Lack of access to the human or financial resources required to implement the interventions, even where doing so would leverage greater benefits to the households involved.

NbS interventions involve actions that can have direct implications for communities that live in or use the areas in question, and can have negative social consequences where traditional access or practices have to be changed as part of the intervention. For example, NbS interventions can involve displacements, change access to land and resources, impact livelihoods and cultural practices (Anguelovski & Corbera, 2023). The 2022 IPCC report acknowledges that there has been a growing global interest in NbS but at the same time warns that its potential negative impacts on local communities needs to be mitigated. For example, government and investors looking to benefit from selling carbon credits from reforestation may lead to the compromise of land rights, dispossession of local communities and deepening of existing climate injustices (Seddon *et al.*, 2020). The expansion of protected areas may also threaten the livelihoods of indigenous people (WEF, 2023). Thus social as well as environmental safeguards need to be incorporated into NbS.

All too often, NbS projects are implemented after too short a period of research and community engagement (Turpie *et al.*, 2024). This can lead to culturally inappropriate designs, can alienate the communities involved, erode their trust and undermine their co-operation. Rather, the approach needs to be slow and thorough. Local communities and indigenous peoples need to be included in decision-making processes involving their land or the land they have custodianship over (WEF, 2023). They need to be involved throughout the decision-making process and given opportunities to actively participate and shape the design of the NbS. Potential conflicts of interests need to be addressed, and all socioeconomic needs should be considered. Genuine partnerships need to be developed which acknowledge indigenous people as stewards of their environment. NbS need to recognise and respect indigenous knowledge and local practices which have historically been used to sustainably make use of ecosystems. Local communities' diverse knowledge can be integrated and enhance the ecological effectiveness and overall success of NbS. If NbS are implemented with strong community engagement and diverse knowledge is integrated, NbS interventions can foster the transformation of social-ecological systems to enhance their sustainability (Palomo *et al.*, 2021). Box 11 showcases two Ugandan carbon forestry projects which demonstrate the importance of including social justice concerns into the development and implementation of such projects.

Lack of local-level capacity is often cited as a major obstacle to the successful implementation of NbS, such as those involving a change in agricultural or grazing practices, or active restoration (Turpie *et al.*, 2024). Building capacities of local communities to implement projects more effectively would improve project effectiveness and the longer term viability of investments (Gómez, Purata & Rodríguez, 2023). Capacity building is not a rapid intervention, it involves long time commitments to build expertise, and can include the use of demonstration areas, farmer field schools, and investing in the tertiary education of future land managers. Without serious investment of this nature, a step often skimped on as a result of investor pressure to generate results, uptake of new technologies can be too slow to yield the benefits estimated in planning. Piloting, demonstration, and training are essential components of a strategic and progressive programme for introducing new measures to communities. Providing evidence (proof of concept) that the planned interventions will work, followed by participatory training and capacity building, through well-tested, participatory approaches can be highly effective at empowering communities and increasing incomes. It is important that the content of the participatory approaches be adapted to the needs and interests of the community.

Even where all the above steps are solidly undertaken, the propensity to adopt new measures in an area might be hampered by landowners' access to resources. The literature has shown convincingly that adoption of more sustainable practices is influenced not only by farmers' risk profiles but by the size of their asset base (e.g. including livestock holdings), their incomes and their access to credit. To effectively implement NbS, it is crucial to address and meet various essential developmental needs that communities may have (Ambrosino *et al.*, 2021). Ensuring access to key resources and services, promotes overall well-being and garners support for the implementation of NbS interventions. Ensuring that communities have access to the necessary basic resources and services, means that they are better positioned to take advantage of available opportunities. It also creates goodwill and cooperation which is important for successful project implementation and ongoing adoption and support. Communities will be more likely to support the proposed conservation or restoration initiatives when their basic needs are met and when they see tangible improvements in their day-to-day lives. Bettering people's lives and pulling them out of poverty ensures the support that is needed over the long-term as well as likely success of the project.

Box 11. Case study: Uganda carbon forestry project (Fisher *et al.*, 2018).

Carbon forestry project design and implementation in Uganda have raised questions of environmental justice. One of the main social justice concerns about such programmes is that comparatively wealthy entities from the global north are seeking to offset their emissions with carbon sequestration in the global south. Thereby, implementing parties often focus on monitoring and evaluation and not on participant's understanding of the interventions. Fisher et al. (2018) assess notions of social justice related to two carbon forestry projects in Uganda: The Trees for Global Benefit (TFGB) programme and the Uganda Wildlife Authority – Forests Absorbing Carbon Emissions (UWA-FACE) programme.

The TFGB programme has been used as an example for well-designed smallholder carbon forestry project in Africa. Local communities seemed to overall perceive the project as just and were willing to cooperate. Landowners who want to become part of the project register at least one hectare of their land for the programme and are required to plant indigenous trees in woodlots and agroforestry systems. Programme participants need to maintain their indigenous tree plantations for 25-50 years and receive 60% of carbon sales with payments being targeted to the household scale.

It was criticised that the TFGB programme lacked procedural justice to ensure that local communities play a role in project design and implementation. The programme had very limited scope to be managed in a participatory manner and left little room for negotiations. Participants evaluated the project considering equity in access to the project and equity in the project's distribution of costs and benefits. Participants were more concerned about cost and benefit distribution than project access.

The UWA-FACE has been perceived as problematic and unjust. The project aimed to reforest 25,000 hectares of Mount Elgon National Park with FACE covering reforestation costs, and Ugandan conservation authorities giving up their rights to market the carbon dioxide from the new plantations. The main planned direct benefit from the programme was employment, contrary to the TFGB programme where participants received direct payments. The carbon project was rejected by local communities and international organisations due to controversial and contested Protected Area boundary enforcements, human right abuses, and flawed surveying practices.

Analysing notions of justice can help understand the outcomes of carbon forestry projects. While the TFGB project met people's distributional concerns and did not raise any significant other justice concerns, the UWA-FACE project was controversial on a number of justice dimensions, ultimately causing the project's decline.

Gender considerations also play an important role. Many societies are strongly patriarchal, in which strongly gendered domestic, livelihood and workplace roles accommodate the reproductive role of women. Men tend to have more access to resources, take more leadership roles, and have more power and voice in decision-making than women, and women also must deal with greater risks to their security. Women, whose work is often closely linked to natural resources, face significant barriers in accessing land, credit, and education, limiting their economic opportunities and contributions to sustainable development. Women play an important role in land-based activities and in adaptation to climate change at the household level and there is significant potential for NbS activities such as climate smart agriculture to help to empower women. Indeed, women's empowerment is needed for the long-term sustainability of the whole system, so that they have more control over their fertility rates and their economic options. Despite this, inclusivity is not always well catered for in the implementation of NbS policies and projects.

Strengthening local governance structures to foster transparency, accountability, and inclusiveness, can lead to more community cohesion and better development outcomes (Odhiambo & Sankale, 2021). Strengthening and guiding local governance and management structures is considered an important supporting intervention as it can help to address a number of key challenges. This should involve providing support and capacity building around roles and responsibilities and best practices (e.g., for local community members who are part of a grazing committee or on the board of the trust for a conservancy). This can play a significant role in strengthening local governance structures by ensuring accountability, improving transparency and addressing issues of corruption. It should involve supporting the development of adaptive plans and systems for the monitoring and evaluation of activities and should focus on providing technical assistance for registration of zoning and land use plans with government.

## FINANCIAL BARRIERS

Because the implementation of NbS often requires high upfront costs at scale, financial barriers are one of the key challenges, necessitating innovative financing solutions and/or external funding. Substantial opportunities exist for funding from the Adaptation Fund, the Green Climate Fund and the Global Biodiversity Framework Fund.

Access to finance has been identified as one of three key barriers that slow down the implementation of NbS (Global Commission on Adaptation, 2019). In 2018, only US$3.8–8.7 billion, or around 0.6%–1.4% of total climate finance flows were provided for adaptation (Swann *et al.*, 2021). Funding for adaptation and mitigation in the "agriculture, forestry, land-use, and natural resource management" sectors in 2018, often used to indicate overall NbS flows, accounted for 3% of all tracked climate finance or 7% of tracked public finance (Swann *et al.*, 2021). Funding for NbS adaptation came from a small number of donors, including the EU, Asian Development Bank, the GCF, and the International Fund for Agricultural Development. Some countries, including Germany, the UK, Japan and Sweden also contributed to NbS for adaptation funding (Swann *et al.*, 2021). Most public NbS for adaptation funding was provided for projects in Sub-Saharan Africa and South and Central Asia (Swann *et al.*, 2021). Sub-Saharan Africa received between US$1.67 and US$2.88 million of official development assistance for NbS adaptation in 2018 (Swann *et al.*, 2021).

Funding for NbS is derived from a combination of private and public sources, such as the GEF, Green Climate Fund, or the Adaptation Fund. Some financing is also generated through PES schemes, which are often part of a larger global initiative, such as REDD+. However, in 2020, only 14% of capital came from private investors, most protection and regeneration projects were funded through the public sector (UNEP, 2021). Box 12 highlights South Africa's approach to acquire enough land to meet the 30x30 protected areas targets.

Public financing alone is not enough to cover NbS' financing gap – private capital will need to be leveraged to build NbS capacity across the globe. Common barriers to private sector finance include uncertainty about the projects' ROI, complex methodologies, and the lack of tax incentives (Gómez *et al.*, 2023). NbS investments are predominantly financed through debt which poses substantial risk on developing countries. Other forms of funding, such as equity with risk sharing agreements, need to be implemented (Seddon *et al.*, 2020). New investors could be attracted through well-designed financial instruments (Gómez *et al.*, 2023). Blending finance from public and philanthropic sources to decrease the investment risk of projects can improve the attractiveness of NbS to private investors. NbS are not promoted enough through existing funding channels and lack clear definitions and standards how to assess their costs and benefits (Swann *et al.*, 2021). Having clear methodologies and goals which are standardised and certified by third parties could also increase confidence in NbS projects. NbS need to show the same rigour regarding objectives and Key Performance Indicators (KPIs) as conventional financing projects (Gómez *et al.*, 2023).

Box 12. South Africa incentivising biodiversity conservation through tax incentives.

Given the large funding gap for biodiversity conservation, economic instruments are required to incentivise private actors and governments to invest in conservation. Fiscal instruments, such as tax incentives for private land users, could help countries make NbS investments more attractive.

South Africa provides private landowners with tax incentives to convert their land to conservation areas. Through the Income Tax Act Section 37D, taxpayers who declare their land as protected area can deduct the value of the land from their income tax (Wilderness Foundation Africa, 2022a). Through this stewardship approach South Africa's protected area estate can be increased without requiring additional government finances. It is hoped that such tax rebates encourage landowners to move away from traditional farming practices and motivate them to rather conserve their land which will allow South Africa to expand its national protected area coverage. The 37D tax benefit was estimated to contribute over R1.4 billion to South Africa's biodiversity finance (Wilderness Foundation Africa, 2022b).

Private sector finance can also be leveraged by incentivising businesses that themselves will assist communities in achieving the aims of NbS projects. For example, blended finance may stimulate investment in joint venture tourism operations in community conservancies, or incentives for agribusiness may stimulate the development of markets for agroforestry products. Improving value addition, strengthening value chains and supporting the establishment of cooperatives creates business interest in assisting local communities to succeed. Developing and/or strengthening value chains can increase rural incomes and strengthen food security and at the same time provide opportunities to farmers to invest in their businesses and boost productivity. Women's inclusion in the development of value chains promotes empowerment and can lead to household-level risk diversification, improvement in children's well-being, and a shift to more sustainable livelihoods. To ensure success, it is recommended that a detailed and contextualised value chain analysis during the initial preparation phase of the project, including engagement and co-participation with the community, be undertaken. Supporting the establishment of farmer cooperatives can improve market participation and increase farmer incomes. Cooperatives facilitate collective action and are organised to improve economies of scale, access to input and output markets, bargaining power and information sharing, and to reduce costs.

## POLITICAL CHALLENGES

Political support for NbS has been low due to uncertainty about its cost-effectiveness, and concerns about the negative social impacts of imposing changes in land use and management. As a result, some of the institutional and policy reforms needed to ensure the success of NbS have not been addressed. However, political support is likely to increase as nature-related risks and opportunities become better understood.

While NbS has been promoted for almost two decades, it has only recently started to gain traction in terms of being incorporated into national and sectoral policies. Governments have been cautious, requiring evidence of its robustness compared with more conventional approaches. Concerns and misgivings are widespread, and include the social concerns outlined above. However, international support or NbS, including significant opportunities for financing, has certainly helped to drive political support for this approach.

Political support will ultimately be revealed by the extent to which governments put in place measures to address some of the underlying issues that hamper the successful implementation of NbS. Key among these are the existence of adequate governance structures and institutional frameworks, including well defined and secure property rights (Nesshöver *et al.*, 2017; Nelson *et al.*, 2020; Morita & Matsumoto, 2021). Mechanisms will need to be in place to ensure cooperative governance across a range of sectors and to be able to implement NbS at scales that transcend jurisdictional boundaries.

Cross-sectoral strategies for NbS tend to be lacking (Morita & Matsumoto, 2021). NbS governance literature therefore suggests a comprehensive governance approach where policies and regulations regarding NbS are coordinated (Nesshöver *et al.*, 2017; Morita & Matsumoto, 2021). Once NbS are implemented, existing regulations need to be adjusted to be aligned with NbS implementation and support them. For example, once landscapes are restored, they need to be better protected (Lewis *et al.*, 2019). Box 13 shows how a badly designed tree-planting policy in Chile has done more harm than good for biodiversity.

NbS require collaboration of multiple stakeholders from government, NGOs, private sector, and local communities. Joint decision-making and active cooperation between different levels of government and various government departments, such as water and sanitation management, urban planning and design, and environmental management, is required for successful implementation of NbS but coordination among them is often limited as they have diverging interests and competences (Egusquiza *et al.*, 2019; Seddon *et al.*, 2020). South Africa has produced some good examples in this regard, such as the Umzimvubu catchment management partnership.

Obtaining political buy-in for NbS will require further efforts to demonstrate the economic, social and environmental case for the approach. For example, in South Africa, support for catchment restoration, though not named as an NbS *per se*, was garnered through the scientific demonstration of its role in securing water flows as well as the employment benefits of labour-intensive restoration (van Wilgen & Wannenburgh, 2016). Raising awareness has been one of the core activities of the Working for Water (WfW) programme, whose campaigns have targeted the forestry industry, plant nurseries, and landowners as well as the general public (van Wilgen & Wannenburgh, 2016).

Box 13. Misguided afforestation policies in Chile.

The Chilean example highlights how a poorly designed tree-planting campaign ends up doing more harm than good for biodiversity and natural forests. The Chilean government supported large-scale afforestation and reforestation through subsidies with the target to expand their forest cover by 100 000 ha by 2030 (Heilmayr, Echeverría & Lambin, 2020). Chile's Decree Law 701 was introduced in 1974 and applied until 2012. Subsidies were paid to private landowners for the planting of commercially valuable trees.

While the subsidies helped to increase overall tree cover, carbon sequestration, native forest extent, and biodiversity was not increased (Heilmayr *et al.*, 2020). Subsidies were poorly targeted and did not only address farmers that would not have engaged in reforestation efforts in the absence of payment. The subsidies also had a perverse effect as they incentivised the conversion of natural forest to plantations (Heilmayr *et al.*, 2020). Native forests in Chile are more carbon dense and biodiverse compared to plantations. The subsidies hence did not increase carbon storage and had a negative impact on biodiversity. Additionally, the subsidies incentivised planting trees on shrublands and agricultural lands where indigenous forests may have regenerated naturally (Jordan, 2020).

Policymakers need to ensure better enforced restrictions regarding subsidy payments for areas that used to be forested. Introducing subsidy restrictions and prohibiting replacing native forests with plantations could reduce the negative impacts of tree-planting campaigns.

It will also be important to raise awareness among politicians on the nature and value of ecosystem services in general and the role of natural capital in sustainable development. Embarking on natural capital accounting is an important step in this regard, and one that few countries have made much progress on at this point.

# NbS BEST PRACTICES

## SOUTH AFRICA'S EXPERIENCE

South Africa has extensive experience in the development and implementation of NbS, particularly actions relating to the restoration and management of natural and semi-natural ecosystems. Its programmes in this regard have predated the concept of NbS, and there has therefore been some lag in the recognition of existing activities as part of this newer paradigm.

Most of the country's experience in NbS is embodied in its natural resource management (NRM) efforts under the Expanded Public Works Programs (EPWP). These programmes have involved the restoration and management of landscapes to secure catchment water supply (Working for Water), water quality and flow regulation (Working for Wetlands), watershed services (Working for Ecosystems), coastal rehabilitation and sustainable harvesting (Working for Coast) and the management of fire risk (Working on Fire). NRM Programs such as Working for Water are now recognised as having a substantive adaptation benefit (e.g. Holden *et al.*, 2022). As for NbS in general, many of these would also be expected to have significant mitigation benefits. Although not yet scientifically verified, this likely also includes the programmes that remove woody invasive alien plant biomass, since this biomass increases the frequency of veld fires.

These programmes have been accompanied by significant monitoring and research efforts, that have contributed to a substantive evidence base. While this has highlighted weaknesses in the delivery of nature-based outcomes, it has also produced the means with which to make improvements in programme design. For example, the outcomes of the Working for Water programme have been poorer than hoped due to the prioritisation of job creation outcome metrics, and inadequate focus on follow up efforts to sustain the gains made (van Wilgen *et al.*, 2020). Despite these failings, there are strong indications that such interventions offer substantive future benefits under climate change scenarios that would meet criteria to support their implementation (Holden *et al.*, 2022). South Africa has continued to expand its efforts in NbS and will now benefit from the implementation of several major landscape restoration initiatives being funded through Green Climate Fund and the Adaptation Fund. These include efforts on Eco-DRR, initiatives to address farming practices on smallholder farms, and further measures to address the restoration of water source areas.

The country has also seen significant policy advances in terms of the use of NbS in its metropolitan municipalities. Cities such as Johannesburg, Durban and Cape Town have adopted policies to retain and improve their natural asset bases and to use these strategically in providing flood mitigation, water quality amelioration and amenity benefits, all contributing to improving resilience to climate change (Roberts *et al.*, 2011; Turpie *et al.*, 2017b; Letley *et al.*, 2023; McDonald & Aziz, 2023). There are also efforts to increase tree cover through agroforestry in peri-urban areas.

South Africa has also taken steps towards the implementation of NbS that are primarily designed for climate change mitigation. This has taken a bit longer to develop, probably partly due to the country having relatively limited forest area and low avoided emissions potential. Nevertheless, the potential of soil and vegetation carbon sequestration in agricultural and more natural ecosystems is increasingly realised and is being pursued through the informal carbon market. Research to test the credibility of these approaches has been underway for some years, most notably in the use of Spekboom (*Portulacaria afra*) for ecosystem restoration (Mills *et al.*, 2007), and to some extent in the intensive agricultural space, with tests of alternative cropping systems yielding valuable initial data. The country has undertaken steps to develop a National REDD+ programme, having undertaken a carbon sink assessment in 2015 and set up a consultative team and undertaken a REDD+ Readiness study in 2017 and an exploration of the potential scope of REDD+ implementation in 2020 (DEFF 2020).

South Africa has also made significant progress in the monitoring and analysis of NbS-type interventions, which has contributed to building a well-informed community of practice. According to Nyika & Dinka (2022), 123 studies had been published on theoretical and practical aspects of implementing NbS in Africa at the time of review. South African institutions were by far the most active in this area of work, leading in the production of about 38% of the knowledge products.

## NATIONAL AND INTERNATIONAL BEST PRACTICES

South Africa has already developed best practice guidelines for EbA (DEA, 2018), which would also apply well to the broader concept of NbS. The EbA best practice guidelines, summarised in Figure 6. Authors' summary of the key elements of South Africa's EbA guidelines (DEA, 2018).Figure 6, prescribe four cornerstones for the implementation of interventions, namely that:

- Interventions are responses to current and future impacts of climate change;
- Interventions make use of biodiversity and ecosystem services;
- Interventions support human and societal resilience to climate change; and
- Interventions are contextualised in a paradigm of sustainable development.


Figure 6. Authors' summary of the key elements of South Africa's EbA guidelines (DEA, 2018).

Within the framework of the four cornerstones, a set of seven principles highlighting associated criteria and safeguards were defined to ensure beneficial outcomes for both people and nature under climate change risks. A framework for monitoring and evaluation (M&E) was proposed that advised integration with South Africa's climate change M&E procedures and would furthermore facilitate the development of a strong evidence base for the approach. The EbA best practices document (DEA, 2018) indicated that over-explicit guidelines might disincentivise or impede implementation, but that a lack of clear guidelines could have unintended consequences already highlighted above, namely risks for superficial greenwashing (e.g. Seddon *et al.*, 2020; Seddon, 2022). With respect to advancing implementation of these approaches, DEA (2018) noted important opportunities for alignment with the DFFE existing program of work, with the work of National Sector Departments, and with Municipalities.

When developing best practice guidelines for NbS, building from the basis laid by work already carried out and explored in stakeholder engagements by the EbA stream of work (DEA, 2018), there would be a critical need to engage and align, where appropriate, with guidelines and practices developed and negotiated in the UNFCCC and CBD forums. These include the extensive body of information developed during the development of REDD+ policies under the UNFCCC (including party submissions), the Nairobi Work Program technical work on EbA, IUCN's Global Standard for NbS (2020) and the proposed governance structure, NbS guidelines complementary to the IUCN Global Standard, with the aim to have the guidelines be adopted to the UN Framework Convention on Climate Change (UNFCCC). Academic reviews and assessments would also provide valuable additional perspectives in the development of a robust guideline document (e.g. Seddon *et al.* 2021 "Getting the message right on nature-based solutions to climate change" and Cook-Patton *et al.* 2021 "Natural Climate Solutions hierarchy").

# CONCLUSIONS AND RECOMMENDATIONS

Over the past decade there has been a rapid rise in the prominence of the concept of NbS, which has strong international policy and business support particularly in developed countries. Because of the numerous related terms that have emerged in different parts of the world over the last few decades, the concept of NbS is often confused. EbA encompasses actions to restore or secure ecosystem services that help to address sectoral challenges, climate change adaptation and/or climate change mitigation in a way that also has positive outcomes for biodiversity and is an umbrella term for a number of concepts that include EbA, EbM and EcoDRR. While the term 'approaches' may have been better than 'solutions', which might be interpreted as replacing the need for cutting industrial carbon emissions, efforts to rebrand the concept would likely just hinder progress on the development and implementation of NbS. The risks of over-promise and burden-shifting from alternative approaches such as emissions reductions can be reduced and avoided through clear definition and well-communicated understanding of these risks by concerned parties, matched by efforts to codify risk reduction language in negotiated texts and implementation plans.

There is substantial evidence to suggest that there is a positive economic case for use of NbS in a range of problem contexts. Since those contexts always vary, it will always be necessary to undertake feasibility assessments to investigate potential viability and cost-effectiveness of this approach.  The main barriers are financing, since NbS can involve high up-front costs, and social, since implementation often involves a change in the way that land and resource are accessed or managed, and institutional, in that implementation may not be successful in contexts where property rights are insecure or where there is weak governance. There is limited political support in developing countries, possibly due to limited evidence of its viability, as well as the relatively long time that NbS interventions take to generate benefits relative to conventional engineering projects. However support is increasing as international funds are increasingly being made available to support these efforts.

South Africa already has extensive experience in implementing NbS, particularly interventions to improve water security, and to address climate change adaptation. The guidelines already developed for EbA could easily be repurposed to be guidelines for NbS.  This would expand the guidelines to include more deliberate NbS actions for mitigation, to add to existing commitments in other spheres. Monitoring efforts to date have also allowed rigorous analysis of past strategies that have been able to highlight shortcomings that need to be addressed in order to improve their efficiency. Research also suggests that there could be substantive future benefits of NbS under climate change scenarios.

Overall, the NbS concept provides opportunities to align and cohere multiple climate response options across sectors and at multiple governance scales in South Africa, including bringing together mitigation and adaptation options identified in several climate policy relevant initiatives ranging back to processes like the Long Term Mitigation Scenarios initiative from the 2000s. NbS can be linked to the achievement of Sustainable Development Goals and commitments under the CBD, providing opportunities to achieve numerous goals and targets in a more integrated way, as envisaged by concluding findings of recent cross-convention assessments by the Intergovernmental Platform on Biodiversity and Ecosystem Services. South Africa's experience in developing guidelines in EbA provides a strong foundation to develop nationally and regionally relevant policy to optimise opportunities and reduce the risks identified of inappropriate NbS implementation.

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