



Core principles for successfully implementing and upscaling Nature-based Solutions

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ABSTRACT

Despite substantial increases in the scope and magnitude of biodiversity conservation and ecological restoration, there remains ongoing degradation of natural resources that adversely affects both biodiversity and human well-being. Nature-based Solutions (NbS) can be an effective framework for reversing this trend, by increasing the alignment between conservation and sustainable development objectives. However, unless there is clarity on its evolution, definition and principles, and relationship with related approaches, it will not be possible to develop evidence-based standards and guidelines, or to implement, assess, improve and upscale NbS interventions globally. In order to address this gap, we present the definition and principles underpinning the NbS framework, recently adopted by the International Union for Conservation of Nature, and compare it to (1) the Ecosystem Approach that was the foundation for developing the NbS definitional framework, and (2) four specific ecosystem-based approaches (Forest Landscape Restoration, Ecosystem-based Adaptation, Ecological Restoration and Protected Areas) that can be considered as falling under the NbS framework. Although we found substantial alignment between NbS principles and the principles of the other frameworks, three of the eight NbS principles stand out from other approaches: NbS can be implemented alone or in an integrated manner with other solutions; NbS should be applied at a landscape scale; and, NbS are integral to the overall design of policies, measures and actions, to address societal challenges. Reversely, concepts such as adaptive management/governance, effectiveness, uncertainty, multi-stakeholder participation, and temporal scale are present in other frameworks but not captured at all or detailed enough in the NbS principles.

This critical analysis of the strengths and weaknesses of the NbS principles can inform the review and revision of principles supporting specific types of NbS (such as the approaches reviewed here), as well as serve as the foundation for the development of standards for the successful implementation of NbS.

1. Introduction

The relentless drive for economic growth along with the increase in

global population has resulted in a surge in natural resources consumption, biodiversity loss, pollution and land degradation, while also compromising social equity and human well-being (WWF, 2016).

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Humanity and other life on the planet may be approaching a catastrophic tipping point (Rockström et al., 2009; Steffen et al., 2015; IPCC, 2018), creating an urgent need for innovative approaches to ecological restoration, nature conservation, and addressing global societal challenges to meet society's needs. Current approaches to restoration and conservation are not occurring at a scale that can redress degradation (Holl, 2017). To address global societal challenges¹ at the required scale, it is necessary to develop specifically designed large-scale, innovative and policy coherent solutions. One way to do so is by implementing a rigorous, evidence-based *Nature-based Solutions* (NbS) framework.

NbS are defined by the International Union for Conservation of Nature (IUCN) as “actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits” (Cohen-Shacham et al., 2016)². The NbS framework emerged from the Ecosystem Approach, which underpins the Convention on Biological Diversity (CBD) and considers biodiversity conservation and human well-being to be dependent on functioning and resilient natural ecosystems (CBD, 2004). With 168 signatory nations to the CBD, the Ecosystem Approach has helped to shape the current conservation and natural resource management agenda.

The NbS concept is increasingly being referred to in scientific literature (e.g., Kabisch et al., 2016; Raymond et al., 2017a; Keesstra et al., 2018) and within governmental and non-governmental policies and programmes (WWAP, 2018). One reason for its wide adoption is that the concept of nature providing solutions is simple in construct and logical for non-specialist understanding. This has encouraged its uptake in policy, practice and by the private sector (Nesshöver et al., 2017), and facilitates opportunities to bring together diverse sectors and stakeholders (Van Ham and Klimmek, 2017). Nevertheless, there is a risk that NbS will remain a vague term, without operational rigor (Nesshöver et al., 2017; Nature, 2017). Although too much detail can stall adoption and rapid uptake of new ideas and initiatives, for concepts to endure, they require clear definitions, parameters and methodologies (Davis, 2008; Brandt et al., 2013). For example, although the Landscape Approach has defined principles (Sayer et al., 2013), there are over 80 definitions of integrated landscape management (Denier et al., 2015) and its lack of a solid, well-defined framework can have adverse impacts on how the principles are coordinated, tested, and applied (Erbaugh and Agrawal, 2017). For NbS to be effectively implemented at the scale needed to reverse ecosystem degradation trends, they need clear and coordinated principles, on which evidence-based standards and guidelines for practitioners and decision-makers can be developed.

Currently, there is a considerable effort being invested into developing principles, standards or guidelines for global ecosystem-management initiatives that fall within NbS. For instance, the Society for Ecological Restoration is in the process of revising its standards of practice (McDonald et al., 2016), and revised principles were recently released for Forest Landscape Restoration to increase clarity on the types of activities that qualify (Besseau et al., 2018). Without clear principles and standards, activities undertaken to improve ecosystem integrity and human wellbeing may have unintended consequences (Gann et al., 2018). In order to improve standards of practice across the multiple types of NbS, we review the development of the NbS concept in a global environmental policy context; present in detail IUCN's NbS framework and its eight preliminary principles (hereafter referred to as “NbS principles”); analyze for the first time the similarities and

differences between principles in five approaches - the Ecosystem Approach, which was the foundation to the NbS framework, and four ecosystem-based concepts that fall under the NbS umbrella (Forest Landscape Restoration, Ecosystem-based Adaptation, Ecological Restoration and Protected Areas) (See Table 1); and identify gaps in the NbS definitional framework that will serve to improve future development of the NbS operational framework. Specifically, we address two questions: (1) Are the current NbS principles sufficiently comprehensive to support the NbS framework and encompass the range of approaches considered as NbS, or are their gaps in the framework that should be addressed?; and, (2) Do the NbS framework and its principles augment and improve existing approaches? This critical analysis of the NbS framework will serve as a foundation for future development of NbS standards and guidelines for improved conservation and development.

2. NbS development in a global environmental policy context

The concept of NbS has its roots in the relationship between biodiversity and human well-being. Although this relationship has been recognized for centuries in traditional knowledge (Berkes, 2012), its framing as ‘ecosystem services’ only started to appear in the scientific literature in the 1970s (Westman, 1977; Gómez-Baggethun et al., 2010). Strong evidence linking global ecosystem degradation to the reduced provision of ecosystem services and a decline in human well-being was released in 2005 under the Millennium Ecosystem Assessment (MEA). This emphasized the interdependence of people and nature, and the MEA called to action for improved conservation, restoration and sustainable ecosystem management to reverse this decline (Millennium Ecosystem Assessment (MEA), 2005).

Since the MEA, knowledge about ecosystem services is being valued, adapted and mainstreamed in national and global policy contexts (FAO, 2016; Geijzenborffer et al., 2017). The Intergovernmental science-policy Platform for Biodiversity and Ecosystem Services (IPBES) has introduced the concept ‘Nature's Contribution to People’ (Díaz et al., 2018) to better emphasize the importance of cultural context and values, and the importance of including diverse and less-represented knowledge systems (Peterson et al., 2018; Masood, 2018).

In the late 2000s, nature conservation experienced a paradigm shift that evolved from focusing solely on nature, to focus on people and nature (Mace, 2014). Nature-based Solutions is part of this shift, whereby people moved from being passive beneficiaries of nature, to proactively protecting, managing or restoring ecosystems as a contribution to addressing a range of major societal challenges. Although NbS have been implemented for a long time in specific contexts (e.g., mangrove restoration and management interventions from the early 20th century, Kairo et al., 2001), the realization and the opportunity for their broader use, at larger scales, has grown significantly in the last two decades. The development of NbS occurred in parallel with the conceptual development of other types of interventions that fall under its umbrella, such as ecosystem-based adaptation (CBD, 2009) or ecosystem-based disaster risk reduction (PEDRR, 2010), and was preceded by concepts such as ecological restoration (SER, 2004) and ecological engineering (Odum and Odum, 2003). Different NbS interventions, including in protected areas, have long supported social challenges such as food and water security (Boelee et al., 2017), disaster risk reduction, and mitigation or adaptation to climate change, while improving sustainable livelihoods and protecting ecosystems and biodiversity (Mittermeier et al., 2008; World Bank, 2008; Dudley et al., 2010).

Over the last five years, further work has been done to clarify the definition of NbS. Eggermont et al. (2015) characterized NbS along two gradients: (i) “how much engineering of biodiversity and ecosystems is involved in NbS”; and (ii) “how many ecosystem services and stakeholder groups are targeted by a given NbS”. The typology highlights that NbS can involve very different actions on ecosystems (from protection to management and even creation of new ecosystems) and assumes that the higher the number of services and stakeholder groups

¹ Societal challenges include climate change, food and water security, natural disasters, human health, and economic and social development (Cohen-Shacham et al., 2016).

² Each of the terms used in the definition have a particular meaning in the NbS context and are clarified in Table S1 in the Supplementary Materials.

Table 1
Details of the five ecosystem-based approaches analyzed in this manuscript, including the definition, purpose, and references for further information.

Name	Definition	Purpose	References and case-studies
Under the NbS umbrella	<p>Ecosystem Approach Strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way (CBD, 2004).</p> <p>Forest landscape restoration The long-term process of regaining ecological functionality and enhancing human well-being across deforested or degraded forest landscapes (IUCN and WRI, 2014).</p> <p>Ecosystem-based adaptation 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).</p> <p>Ecological restoration The process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed (SER, 2004).</p> <p>Protected Areas A clearly defined geographical space, recognized, dedicated and managed through legal or other effective means to achieve the long-term conservation of nature with associated ecosystem services and cultural values (Dudley, 2008).</p>	<p>Primary framework developed to implement CBD (CBD, 2004).</p> <p>To address the need for large scale forest restoration.</p> <p>To address the effects of climate change via adaptation measures.</p> <p>To reverse degradation induced by unsustainable human activity on ecosystems.</p> <p>To conserve nature (biodiversity and geodiversity) and to provide a range of ecosystem services that do not conflict with nature conservation.</p>	<p>Andrade Pérez, 2008 Shepherd, 2004 CBD, 2004 Mansourian and Vallauri, 2014 IUCN and WRI, 2014 Colls et al., 2009 Andrade Pérez et al., 2010 CBD, 2009 McDonald et al., 2016 SER, 2004 Sinclair and Norton-Griffith, 1979 Dudley, 2008</p>

targeted, the lower the capacity to maximize the delivery of each service and simultaneously fulfil the specific needs of all stakeholder groups.

The European Commission defined NbS as “solutions inspired and supported by nature, designed to address societal challenges which are cost-effective, simultaneously provide environmental, social and economic benefits, and help build resilience” (European Commission, 2016; Raymond et al., 2017a). Biomimicry - the practice of examining nature’s models, design and processes, and imitating or taking inspiration from it to solve human problems (Benyus, 1997) - is sometimes confused with NbS as inspired by nature, but it is not considered an NbS as it is not connected to natural ecosystems. Via biomimicry, new material or items are artificially created, mimicking natural ones at different scales (including at the microscopic one) and are used in fields such as architecture, medicine or industrial design. The European Commission’s framing for NbS also focused on ‘innovating with nature’, for more sustainable and resilient societies, through growth and job creation mostly in European and urban contexts (Maes and Jacobs, 2015). The framing of the European Commission has a larger focus on urban ecosystems, due to the high percentage of the population of Europe that lives in cities and the need to address challenges such as human health, climate change, and degradation of natural capital (Faivre et al., 2017; Raymond et al., 2017b). IUCN’s definition was developed from a global perspective, considering all types of ecosystems, but focusing primarily on protection and management of natural ecosystems (*i.e.*, corresponding to NbS types 1 and 2 in Eggermont et al., 2015). The creation of “new ecosystems” (*i.e.*, corresponding to NbS type 3 in Eggermont et al., 2015) would only be included in IUCN’s definition when the purpose is to address particular societal challenges within a landscape, for example, in a newly constructed wetland to remove nutrients (Haase, 2017). While acknowledging the utility and need for them in specific contexts, the IUCN definition excludes the creation of interventions that are inspired by nature.

Considering its overarching goal to address global societal challenges, NbS has the potential to substantially contribute to the 2030 Agenda for Sustainable Development’s targets and to help achieve the full range of Sustainable Development Goals (SDGs) (SDGs, 2017; Faivre et al., 2017). Specifically, NbS are directly relevant to SDG 2 (food security), 3 (health and well-being), 6 (clean water and sanitation), 11 (sustainable cities and communities), 13 (climate change), 14 (conservation and sustainable use of oceans, seas and marine resources), and 15 (protection, restoration and promotion of sustainable use of terrestrial ecosystems) (Lo, 2016; Dudley et al., 2017; Vasseur et al., 2017).

3. Proposed IUCN framework for NbS

3.1. NbS conceptual framework

NbS can be considered an umbrella concept covering a range of ecosystem-based approaches that address specific or multiple societal challenges (Cohen-Shacham et al., 2016; Fig. 1, lower circles), while simultaneously providing human well-being and biodiversity benefits. For convenience, approaches that nest under NbS can be placed into five categories (see conceptual representation in Fig. 1):

- Restorative (Ecological restoration, Forest landscape restoration, Ecological engineering);
- Issue-specific (Ecosystem-based adaptation; Ecosystem-based mitigation; Ecosystem-based disaster risk reduction; Climate adaptation services);
- Infrastructure (Natural infrastructure; Green infrastructure);
- Management (Integrated coastal zone management; Integrated water resources management);
- Protection (Area-based conservation approaches, including protected area management and other effective area-based

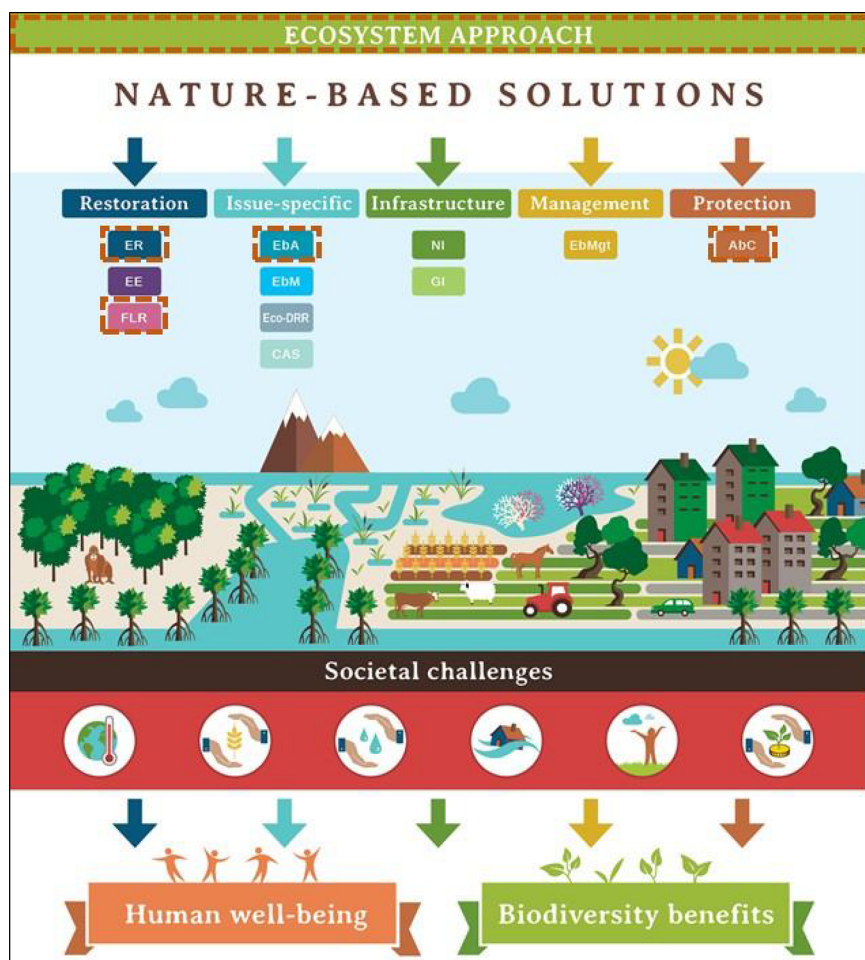


Fig. 1. Conceptual representation of the NbS umbrella for five categories of ecosystem-based approaches (adapted from Fig. 6 Cohen-Shacham et al., 2016). Acronyms used: Ecological Restoration (ER); Ecological Engineering (EE); Forest Landscape Restoration (FLR); Ecosystem-based Adaptation (EbA); Ecosystem-based Mitigation (EbM); Climate Adaptation Services (CAS); Ecosystem-based Disaster Risk Reduction (Eco-DRR); Natural Infrastructure (NI); Green Infrastructure (GI); Ecosystem-based Management (EbMgt); Area-based Conservation (AbC). The approaches in brown dashed boxes are those selected for the comparative analysis. The lower circles represent the societal challenges they address: climate change, food security, water security, disaster risk, human health, and social and economic development.

conservation measures).

3.2. NbS principles

IUCN and its Commission on Ecosystem Management (CEM)³ have been developing the NbS definitional framework, to clarify NbS and enable it to be operationalized. To consolidate the institution's thinking, the principles were developed as a means to help IUCN and other organizations build a common language and understanding of NbS. Practically speaking, a list of 8 principles was put together as a result of internal IUCN and CEM consultation processes and a workshop that resulted in a draft definitional framework for NbS (definition, objective and list of principles); submission of a policy document for IUCN and its membership to consider, 6-months public review; and its formal endorsement as a policy for IUCN and its constituent members ("Defining Nature-based Solutions" Resolution; IUCN, 2016) at the 2016 World Conservation Congress. Many of the principles are linked and, in some circumstances may be interdependent. Given the complexity of the societal challenges that NbS aim to help address, the principles are further elaborated here to be understood in the wider context of sustainable development.

Principle 1: NbS embrace nature conservation norms (and principles): NbS is not an alternative to or a substitute for nature conservation, which remains an important global priority in its own

³The IUCN Commission on Ecosystem Management (CEM) is a global network of researchers and practitioners, who provide expert guidance on integrated management approaches of ecosystems, to promote effective biodiversity conservation and sustainable development.

right. While NbS embrace nature conservation, not all conservation actions necessarily qualify as a NbS (Watson et al., 2014). NbS can be complementary to and benefit from nature conservation efforts across a landscape (e.g., when a protected area was established to conserve a certain species, but later contributes to an NbS intervention nearby - see Cohen-Shacham et al., 2016 for more details). In some cases, NbS closely address biodiversity conservation priorities, but not invariably.

Principle 2: NbS can be implemented alone or in an integrated manner with other solutions to societal challenges (e.g., technological and engineering solutions). NbS promotes the provision of a full range of ecosystem services or be complementary to other actions, such as a mixture of seawalls and mangroves protecting a coastline from ocean surge (e.g., Collenbrander et al., 2013). This principle requires policy coherence and thus is linked to NbS Principle 8 (NbS8).

Principle 3: NbS are determined by site-specific natural and cultural contexts that include traditional, local and scientific knowledge. NbS are evidence-based approaches built on a thorough understanding of particular ecosystems. However, evidence can come from various sources, including science, traditional knowledge, or a combination of the two. Because all situations are different, NbS should consider natural and cultural contexts that include traditional, local and scientific knowledge, through people living and having a stake in the ecosystem. In addition, this principle refers to the need for full participation in developing a NbS.

Principle 4: NbS produce societal benefits in a fair and equitable way in a manner that promotes transparency and broad participation. NbS interventions for food and water security, or disaster risk reduction, frequently provide services for governments and communities distant from the site but can entail loss of opportunities for those living in or near the services' source. It is important to ensure

that different categories of stakeholders are involved in the NbS, that the NbS in place provides benefits to affected actors, from local communities to infrastructure managers/private sector up to national level, and ensure that loss of local opportunities is avoided. For example, when a community maintains a forested watershed to supply water downstream, fair and transparent processes as well as an explicit understanding of the local politics of negotiations and implementations are needed. This understanding should reflect the values of the watershed to the forest community and help determine the nature of compensation-based mechanisms for the supply of ecosystem services, such as through Payment for Ecosystem Service schemes (Wendland et al., 2010; Kovacs et al., 2016), provided the services are maintained.

Principle 5: NbS maintain biological and cultural diversity and the ability of ecosystems to evolve over time. NbS need to be developed and implemented in a manner that is consistent with the temporal dynamics and complexity of ecosystems, in order to support biological and cultural diversity, so that the services provided by the ecosystem are sustainable and, as far as possible, resilient to future environmental change.

Principle 6: NbS are applied at a landscape scale. Many NbS are implemented over large spatial scales - such as watersheds or large forests - which usually combine several ecosystems (agricultural, inland waters, coastal, forest, etc.), and that might in some cases, be trans-boundary. This principle is linked to NbS4 and NbS8. Even when an NbS is implemented at a specific site level (linked to NbS3), it is important to consider the wider landscape-scale context and consequences, aiming at upscaling where appropriate.

Principle 7: NbS recognize and address the trade-offs between the production of a few immediate economic benefits for development, and future options for the production of the full range of ecosystem services. NbS should avoid changing or simplifying an ecosystem, in favor of a particular service or resource, such as replacing natural mixed woodland with a monoculture tree plantation. Instead, a thorough understanding of tradeoffs between current and future benefits is important when deciding among different NbS activities. Understanding and providing a process for fair and transparent negotiation of trade-offs are essential for ensuring successful NbS (Maginnis et al., 2004). Landscapes may contain different stakeholder groups that use resources for their livelihood, which may result in complex and conflictual relationships that need to be identified and negotiated. Hence the need for NbS8 to support NbS7 and the complexity of negotiating trade-offs.

Principle 8: NbS are an integral part of the overall design of policies, and measures or actions, to address a specific challenge. For NbS interventions to have broad influence, it is important to make sure that they are not only practically undertaken in the field, but are also incorporated in policy and related actions. The implementation of this principle will support large scale interventions (NbS6) and it includes the potential for adaptive management (as the interventions' outcomes can inform and adapt natural resource management policy).

4. Comparison of NbS principles and those in related ecosystem-based approaches

4.1. Method

To identify published frameworks for ecosystem-based management approaches, we conducted expert consultations and a literature review. Experts from IUCN CEM, who work on different types of approaches (e.g. ecosystem-based disaster risk reduction, ecological restoration, forest landscape restoration, ecosystem-based mitigation and adaptation, ecosystem services, resilience, green infrastructure, natural infrastructure, etc.), were consulted individually and through the CEM NbS Thematic Group, to identify ecosystem-based and ecosystem-related approaches. Once relevant approaches (17) had been identified through the consultation process, we searched Google and Google Scholar to

identify which of the identified approaches had published operational frameworks, including principles. We searched for publications, documents, and web pages that had the name of one of the identified approaches and one of the following words related to principles and standards: “principles”, “operational framework”, “standard” or “guidelines”. We then screened the collected information to select those approaches that met the following criteria: 1) had a clearly articulated set of principles; 2) had principles that were operational (as opposed to more general, or theoretical types of principles); 3) had principles that were comprehensive enough, to cover a wide range of aspects; to be comparable to the NbS principles. This process yielded four frameworks for analysis: Forest Landscape Restoration (FLR) (IUCN and WRI, 2014), Ecosystem-based Adaptation (EbA) (Andrade et al., 2012), Ecological Restoration (ER) (McDonald et al., 2016) and Protected Areas (PA) (Dudley, 2008). For each of these four approaches, as well as NbS and the Ecosystem Approach, we recorded the complete list of principles. For ecological restoration, we recorded ideas that were labelled both as “principles” and as “key concepts”, because the key concepts were similar in purpose and function to ideas labelled as “principles” in other frameworks (McDonald et al., 2016). Similar to Waylen et al.'s (2014) work, we compared the eight NbS principles with principles in: (1) the Ecosystem Approach; and (2) the four selected approaches⁴, which are activities that fall within the NbS umbrella (see full lists of principles in S2 in Supplementary materials). We analyzed the principles and accompanying text for each framework, and identified similarities in words and ideas, as well as gaps among the principles of the different frameworks.

4.2. Results

Only three of the eight NbS principles (1, 3 and 4) overlap with principles in all the other five approaches analyzed (Table 2), with the number of times they are being referenced in principles from the other approaches ranging from one to three (Fig. 2). Two of the NbS principles (5 and 7) overlap with principles in four of the other approaches: the EbA principles don't refer to maintaining biological and cultural diversity nor to the ability of ecosystems to evolve over time, as it is put forward through NbS5; and the PA principles don't refer to addressing tradeoffs (between immediate economic benefits for development, and future options for the production of the full range of ecosystems services) as mentioned in NbS7.

In contrast, the other three NbS principles (2, 6 and 8) only overlap with principles in one of the five approaches. **Principle 2, on the possibility for NbS interventions to be implemented alone or in an integrated manner with other solutions**, only overlaps with PA7, which suggests using “a diversity of management approaches” (Dudley, 2008), thus referring to the need for integration of broad development interventions.

Principle 6, on the need for NbS to be implemented at a landscape scale, only overlaps with FLR1, which specifically focuses on landscapes (IUCN and WRI, 2014). This principle refers to the importance of having NbS planned in full awareness of the wider landscape context and to consider operating at a large spatial scale (to tackle global societal challenges). While NbS3 and NbS6 differ in the spatial scale they address, with NbS3 considering elements linked to smaller spatial scales, the landscape-scale approach may be made up of a series of site-level connected interventions. Finally, NbS6 also alludes to the potential for promoting interaction across multiple scales (Anderies et al., 2006), which is particularly valuable when managing resources across boundaries. Consequently, although “upscaling” is not specifically written in this principle, NbS6 captures the “upscaling” concept and aims at developing and applying large-scale solutions to address

⁴ Forest landscape restoration; Ecosystem-based adaptation; Ecological restoration; Protected areas.

Table 2
The concurrence of IUCN NbS principles with the Ecosystem Approach and four related approaches. Data represent the number of concurrent principles in each set and the numbers in brackets reference the relevant principle(s) in each set (see S2 in Supplementary materials). For ecological restoration, the key concepts were used as principles.

IUCN NbS principles	Under the NbS umbrella				
	Ecosystem Approach	Forest landscape restoration	Ecosystem-based adaptation	Ecological restoration	Protected areas
1. NbS embraces nature conservation norms and principles	2 (EA5, EA10)	3 (FLR1, FLR2, FLR7)	1 (EbA1)	2 (ER3, ER4)	2 (PA2, PA10)
2. NbS can be implemented alone or in an integrated manner with other solutions to societal challenges (e.g., technological and engineering solutions)	2 (EA1, EA11)	1 (FLR6)	2 (EbA6, EbA7)	3 (ER1, ER2, ER5)	1 (PA7)
3. NbS are determined by site-specific natural and cultural contexts that include traditional, local and scientific knowledge	2 (EA2, EA12)	3 (FLR3, FLR4, FLR5)	2 (EbA5, EbA7)	1 (ER6)	2 (PA3, PA5)
4. NbS produce societal benefits in a fair and equitable way in a manner that promotes transparency and broad participation	2 (EA6, EA8)	2 (FLR2, FLR8)	2 (EbA4, EbA5)	3 (ER1, ER2, ER6)	1 (PA1)
5. NbS maintain biological and cultural diversity and the ability of ecosystems to evolve over time	2 (EA3, EA4)	1 (FLR1)	2 (EbA1, EbA2)	1 (ER2)	3 (PA1, PA2, PA10)
6. NbS are applied at a landscape scale		1 (FLR4)			
7. NbS recognise and address the tradeoffs between the production of a few immediate economic benefits for development, and future options for the production of the full range of ecosystems services					
8. NbS are an integral part of the overall design of policies, and measures or actions, to address a specific challenge					

global societal challenges.

Principle 8, on the need for NbS to be an integral part of the overall design of policies, measures and actions to address societal challenges, only overlaps with EbA1 and EbA2, which refer to “ensuring that national institutions and key decision-makers at different levels promote EbA” and to “multi-stakeholder processes being established when developing adaptation policy”, respectively.

When comparing the wording used in the NbS principles with those in the five analyzed frameworks, there are some similarities and differences. NbS6, similar to the FLR principles, specifically refers to landscape scale. In contrast, EA7 refers to the “appropriate spatial scale” at which the intervention should be undertaken, without specifying at which scale the EA should be implemented. Similarly to EA7, EbA3 and ER2 refer to the multiple scales at which EbA operates, including the landscape scale.

A number of terms are used in other approaches’ principles but they are either not used, or their importance is not sufficiently emphasized in the text of the NbS principles. This includes “adaptive management/governance”, “effectiveness”, “uncertainty”, “multi-stakeholder participation”, and “temporal scale” (see Table 3 for detailed gaps).

5. Discussion

Understanding the extent to which NbS principles are related to or differ from other relevant approaches is an important part of refining, improving, and operationalizing the NbS framework, as well as other ecosystem management approaches. The increase in awareness about the importance of ecosystems and the services they provide worldwide allows improving conditions for both biodiversity and human well-being. To maximize the benefits that ecosystem management provides to conservation, it is important to have a strong set of aspirational principles and apply these to standards of practice.

5.1. What is novel about the NbS framework?

Although we found consistency among ecosystem-based approaches with respect to some NbS principles, we also found that the NbS framework goes beyond the other approaches in integrating other types of solutions, matching the scale of the solution to the scale of the problem, and having an explicit focus on integrating NbS in policy and actions. This difference in focus between NbS and other approaches suggests that NbS is an umbrella for the others, providing ways in which they can work at larger scales, towards policy coherence, and in synergy with other methods

Taken together, the three principles (2, 6 and 8) that were largely restricted to NbS call for integrating management activities with landscape-scale planning and policy, which is increasingly recognized as central to the success of improving ecosystems and human wellbeing. First, NbS has an explicit focus on integration with other types of solutions (NbS2). This integration allows for a broader range of social and environmental benefits to be supported and developed through targeted but connected interventions, and can help remove barriers between existing frameworks to better integrate learning from different approaches. This places NbS firmly away from mainstream biodiversity conservation approaches that predominantly focus on species or ecosystem conservation (Mace, 2014) and emphasizes its role as a tool for sustainable development based on healthy ecosystems, rather than being concerned with conservation for its own sake.

Another novel aspect of NbS is the consideration of the landscape context (NbS6), which is critical to the success of management interventions for multiple reasons. If site-specific actions are implemented without considering causes of degradation, any short-term benefits of the management activity may be lost if external threats continue to degrade the site. Also, planning at the landscape scale allows for consideration of ecological interactions among ecosystems within the landscape, such as ecological subsidies that may enhance or hinder

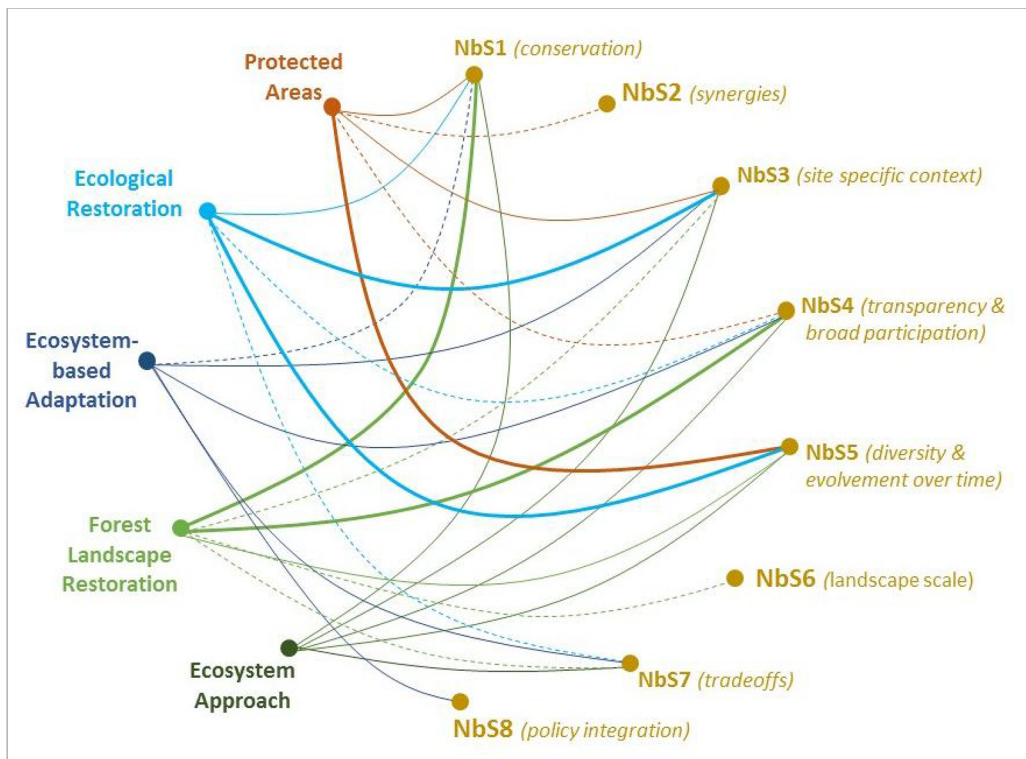


Fig. 2. Extent to which each of the eight NbS principles is included within the principles of the other five analyzed approaches. Line weight represents the number of times the NbS principle is referenced in the principles of other frameworks’ (dashed lines = one time, thin lines = two times, thicker lines = three times). Codes for each NbS principle are provided in Table 1.

potential for management success. Despite widespread agreement about the importance of planning and implementing ecosystem management approaches at the landscape scale, there are several obstacles to successfully working at this scale, including limited available funding, legal and mandate limitations, administrative boundaries, human capacity, technical limitations including data and institutional hierarchies.

Finally, a third novel aspect of NbS is the focus on coordinated efforts (NbS8), that addresses the complex interactions between ecological, social, legal, institutional and political systems that transcend site-level approaches. The integration is there to ensure that global societal challenges are addressed at the scale of the problem and promote broader programmatic and policy interventions than piecemeal projects.

In sum, the NbS principles allow for the integration of solutions (e.g., use of grey infrastructure, public awareness tools), landscape-scale planning and policy coherence, all in one single framework. An example of a successful, integrated NbS intervention is Medmerry’s

coastal defense managed realignment in South-East England, and its integration into a larger coastal defense strategy (Pearce et al., 2011), which helped ensure that ecological engineering at that site was connected to similar interventions along the coast and so have a large impact on reducing erosion along the coast.

Although NbS may not be a perfect umbrella concept for other approaches, it does complement principles from these other approaches, by being more extensive and ambitious on social and economic challenges beyond conservation alone, thus acting as an environmental mainstreaming tool into policy and practice.

One important caveat to our findings is that we based our analysis solely on a comparison of principles. Some frameworks included principles and standards of practice. In cases where certain concepts in the NbS principles were not included in the principles of another framework, they may have been included in the standards for that framework. For instance, the standards of practice for ecological restoration (McDonald et al., 2016) has a large focus on landscape context and external threats; however, the use of the landscape approach is

Table 3
Specific terms missing or not sufficiently emphasized in the NbS framework.

Terms not/weakly emphasized in NbS principles	Specific reference of these terms in other ecosystem-based related approaches (principles in brackets)
Adaptive management / governance	Forest Landscape Restoration’s Principle 8 (FLR8) and Ecosystem-based Adaptation’s Principle 4 (Eba4) refer to adaptive management.
Effectiveness	Protected Areas Principles 6 (PA6) and 7 (PA7) refer to governance and diversity of management approaches. The effectiveness of the intervention is specifically referred to in the Ecosystem Approach’s Principles 2 and 11 (EA2, EA11), Eba4 and PA9.
Uncertainty	EA9 refers to change as being inevitable (“Apart from their inherent dynamics of change, ecosystems are beset by a complex of uncertainties”).
Multi-stakeholder participation (NbS4 only partly refers to broad participation)	Ecosystem Restoration Principle 1 (ER1) refers to the need to take environmental changes into account. FLR5 specifically refers to multi-stakeholder engagement.
Temporal scale	Eba2 and Eba4 refer to multi-stakeholders’ participation as part of multi-sectoral approaches and adaptive management. Ecological Restoration Principle 6 (ER6) promotes early, genuine and active engagement with all stakeholders. ER2 refers to long-term goals and shorter terms objectives, and ER6 refers to long-term restoration success. EA7 refers to the “appropriate temporal scale” at which the intervention should be undertaken, and EA8 to the fact that the objectives should be set for the long term. Eba4 refers to long-term monitoring systems as part of adaptive management, but it doesn’t specifically refer to long-term interventions.

emphasized in the standards of practice for ecological restoration, rather than the principles. To effectively communicate ecosystem management frameworks, there is a need to align concepts within standards of practice with those within principles. One important outcome of our assessment of principles is that it has already created a dialog among members of the conservation community working to define frameworks for ecosystem management to has identified inconsistencies in framing.

For frameworks to reflect the best thinking in science and practice, they must be continually updated. Towards this end, some of the frameworks we studied were undergoing revisions to their principles or standards during the period of our study (material collection occurred between 09/2017–11/2017). Thus, their revised frameworks may now include concepts that we report as missing from their principles. As an example, Forest Landscape Restoration's latest version of its principles are dated, and a revised version of the principles and standards of practice for ecological restoration will be released in 2019 and are intended as an update to McDonald et al. (2016). Our analysis is based on frameworks that were published by November 2017.

5.2. What areas of the NbS approach is deficient or limiting relative to other principles?

Our finding that some key concepts included in other approaches are not emphasized in NbS suggests that the NbS framework requires attention in several key areas. First, NbS principles do not currently adequately address *uncertainty*. Since ecosystems are self-organizing and evolve in response to multiple interactions across many levels of scale, the outcome of management interventions cannot be predicted with certainty. The difficulties of and methods for managing uncertainty could be more clearly articulated in the NbS framework with reference to the benefits of deep reflection as part of experiential learning (Kolb, 1984) and as an essential component of adaptive management and governance of complex systems (Burns and Worsley, 2015; Rogers et al., 2013).

Although the *temporal scale* is vaguely addressed in the NbS principles, with NbS5 referring to the importance of “maintaining biological and cultural diversity for the ecosystems to evolve over time” and NbS7 referring to trade-offs, the NbS framing could be more explicit about long-time stability. For instance, it could refer to the need for long-term objectives and long-term maintenance of projects to avoid actions that undermine the stabilizing function of ecosystem regulating services.

Monitoring is another concept that was not included in the NbS principles. It relates to both *uncertainty and temporal scale*. Long-term stability depends on the ability of managers to assess the efficacy and effects of management interventions and adapt management accordingly (McShane and Wells, 2004). This means, for example, that monitoring programs must be institutionalized within organizations and stakeholder groups that manage a particular landscape, to achieve a broad range of social and environmental benefits.

Also, although there is some text within the NbS principles referring to the need to manage in accordance with the inherent properties of *ecosystems*, including their *complexity and temporal dynamics*, the principles do not go far enough in discussing how these considerations should or could be addressed in a management context.

Such gaps are important to be identified at this point, to ensure that they are considered and addressed in the development of the NbS operational framework and more specifically while developing the NbS standards.

6. Conclusions and recommendations

As NbS has become better understood and recognized as viable options for development and conservation, there is an opportunity for a rigorous framing of the concept to meet standards for sound management (e.g., IUCN and WCPA, 2016). Despite ongoing efforts to define standards and implementation guidelines - for NbS, ecological

restoration (McDonald et al., 2016), forest landscape restoration (Beatty et al., 2018), ecosystem-based adaptation and disaster risk reduction (CBD, 2018a) - there has not yet been a review of the principles that underlie the ecosystem management approaches being used for conservation. Our comparative analysis of the principles for NbS, the Ecosystem Approach and selected ecosystem-based approaches, identified areas of agreement as well as gaps that should be addressed to improve conservation impact across all types of ecosystem management.

To further operationalize NbS it will be important to assess how the NbS principles are implemented in diverse case-studies and assess more in detail the relevance of NbS in global policy (e.g., SDGs, CBD Aichi Targets). Most importantly, we must demonstrate the value of operationalizing NbS principles 2, 6, and 8, which will enable us to address societal challenges at the scale needed. This will necessitate a high degree of coordination amongst stakeholders, including the public and private sectors. Without this higher level of coordination, piecemeal interventions will be offset by continuing degradation, outpacing any efforts to maintain or restore the earth's ecosystems and their services.

Also, for NbS to effectively serve as an umbrella framework, it will be critical to incorporate key identified gaps (e.g., need for adaptive management and governance, refer more clearly to ecosystem complexity, temporal scale, effectiveness, and uncertainty) in operational documents. This could be in a number of ways: (1) Key missing concepts should be incorporated into the IUCN global standard for NbS, which is currently being developed; or by adding a list of criteria/safeguards addressing these concepts (proposed list of criteria from Cohen-Shacham et al., 2016: Ecological complexity, long-term stability, scale of ecological organization, direct societal benefits, adaptive governance) to future guidelines for best NbS practices. (2) The eight NbS principles could be revised into a more comprehensive framework that would include the missing concepts from other approaches. This could be done by enriching the explanatory text for each principle, by including a larger number of examples at an increasingly larger scale to support evidence building and contextual appropriateness, or by refining the NbS principles text in a format that more consistently fit the SDGs text.

Nature offers solutions that support many other conservation, environmental, and development objectives when integrated with other more conventional sectoral approaches (Holl, 2017). However, a key challenge, and a large opportunity for NbS is the ability to scale-up and to connect and absorb small-scale interventions on the ground into broader and potentially more impactful interventions. Stronger policy coherence as proposed in the NbS framework could help here. It would be beneficial to develop future research to build a robust evidence base for the contribution of NbS to job creation as referred to by the European Commission (European Commission, 2015), and demonstrate the economic viability of NbS in comparison to other types of solutions on a timescale compatible with that of global change. NbS have been identified as a priority area for investment, under Horizon 2020 (Raymond et al., 2017b), and the European Commission has earmarked 240 million Euros to spend on NbS-related projects, by 2020 (CBD, 2018b). Some of the main objectives are to provide the evidence and a knowledge base for NbS and advance the development, implementation and scaling up of innovative NbS (European Commission, 2018). A first step in testing our analysis would be to use it in framing some of the European project calls, and in relation to assessing the implementation of NbS projects at a landscape scale and through policy integration. This effort would help link work being developed by different institutions, and will help to improve how NbS is implemented and ultimately how it can address global societal challenges at the scale required.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.envsci.2019.04.014>.

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