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The science, policy and practice of nature-based solutions: An interdisciplinary perspective



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HIGHLIGHTS

- Nature-Based Solutions (NBS) is a new term in environmental research and management.
- NBS has connections to other concepts for managing and understanding ecosystems.
- Existing experiences provide crucial insights on potential and pitfalls of NBS.
- The multiple dimensions of sustainability provide a framework to plan and assess NBS.
- NBS holds a potential for both stimulating and preventing economic developments.

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ABSTRACT

In this paper, we reflect on the implications for science, policy and practice of the recently introduced concept of Nature-Based Solutions (NBS), with a focus on the European context. First, we analyse NBS in relation to similar concepts, and reflect on its relationship to sustainability as an overarching framework. From this, we derive a set of questions to be addressed and propose a general framework for how these might be addressed in NBS projects by funders, researchers, policy-makers and practitioners. We conclude that:

- (1) NBS need to be developed and discussed in relation to existing concepts to clarify their added value;
- (2) When considering and implementing NBS, the 'relabeling' of related concepts and the misuse of the concept have to be prevented in order to avoid misunderstanding, duplication and unintended consequences;

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- (3) NBS as currently framed by the European Commission provides an opportunity for: a) transdisciplinary research into the design and implementation of solutions based on nature; and b) overcoming a bias towards development alternatives with narrow perspectives that focus on short-term economic gains and effectiveness;
- (4) The strength of the NBS concept is its integrative, systemic approach which prevents it from becoming just another “green communication tool” that provides justification for a classical model of natural resource exploitation and management measures.

To realise their full potential, NBS must be developed by including the experience of all relevant stakeholders such that ‘solutions’ contribute to achieving all dimensions of sustainability. As NBS are developed, we must also moderate the expectations placed on them since the precedent provided by other initiatives whose aim was to manage nature sustainably demonstrates that we should not expect NBS to be cheap and easy, at least not in the short-term.

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1. Introduction: nature-based solutions as a new term in science, policy and practice

Those working in science, policy and practice related to the management of the natural environment regularly encounter new ideas and terminologies. In the late 1980s the phrase ‘sustainable development’ was defined by the United Nations (UN) Brundtland Commission (Brundtland et al., 1987) and then the term ‘biodiversity’ emerged from the field of conservation biology (Takacs, 1996; Wilson, 1988). More recently, the use of ‘natural capital’, from the fields of applied ecology and ecological economics (Daly and Farley, 2011; Jansson, 1994; Costanza and Daly, 1992; Schumacher, 1973) and the idea of ‘ecosystem services’ has become widespread (Costanza et al., 1998; Daily, 1997; MA, 2005; Gómez-Baggethun et al., 2010). These concepts are reflected in policy agreements including the adoption of the Convention on Biological Diversity (CBD) in 1992 (UNEP, 1993) and its Ecosystem Approach (UNEP/CBD, 2000), the UN’s Millennium Ecosystem Assessment (MA, 2005) and its follow-up activities such as the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) (UNEP, 2010). They also shape programmes of research. For example, until 2014 the European Union’s Framework Programmes for research supported many projects focussing on ecosystem services (Admiraal et al., 2016). Over the past twenty years, an increasing number of perspectives have reflected an anthropocentric view of the management of natural resources, including biodiversity and the environment (Nesshöver et al., 2015), with a focus on the benefits that nature may provide for humans (Díaz et al., 2015; MA, 2005; TEEB, 2010a).

The most recent entry to this discourse is ‘Nature-Based Solutions’ (NBS), a concept introduced specifically to promote nature as a means for providing solutions to climate mitigation and adaptation challenges (Cohen-Schacham et al., 2016; IUCN, 2012). Within Europe, policy-makers have integrated the concept into their new framework programme for research and innovation, ‘Horizon 2020’, providing a new narrative involving biodiversity and ecosystem services aligned with goals of innovation for growth and job creation (European Commission, 2015c), and with a potential opening for transformational pathways towards sustainable societal development (Maes and Jacobs, 2015).

Despite limited research about the concept to date (Eggermont et al., 2015; Maes and Jacobs, 2015), the term has already diversified. In the United States ‘nature-based infrastructure’ and ‘engineering with nature’ are more common as descriptions for actions to support resilience and to reduce flood risk (US Army Corps of Engineers, 2013), and the IUCN and EC definitions of NBS provide alternate perspectives on its remit and purpose (Table 1). For the EC, NBS is understood as actions that ‘aim to help societies address a variety of environmental, social and economic challenges in sustainable ways. They are actions which

are inspired by, supported by or copied from nature’ (European Commission, 2015c, p. 5).

Due to these broad framings, the meaning of NBS can appear vague, and the links to pre-existing concepts may be unclear. It has been suggested that the conceptual flexibility associated with a vague or loosely-defined term can risk missing important opportunities to improve the management of natural resources (e.g. Waylen et al., 2014). A comprehensive formulation would definitely help to stimulate discussion and innovation, and facilitate communication among the communities of science, policy and practice (Abson et al., 2014; Brand and Jax, 2007; Star and Griesemer, 1989). However, there is also a danger of oversimplification, reinventing the wheel, (non)deliberate misuse, or generating new, unforeseen trade-offs in decision-making (Bennett et al., 2009; Ring et al., 2010). It is thus important that such a concept, which has emerged at the science-policy-practice interface, is analysed and placed in the context of existing terms and terminologies, and that potential overlaps as well as differences are acknowledged.

In this paper, we reflect critically on the concept from the viewpoint of NBS contributions to sustainable development in Europe. With an aim of providing a basis for researchers and other actors involved in NBS projects, we examine how NBS relate to existing concepts and what implications can be drawn for NBS research, its applications and to inform policies. Firstly, we consider how NBS refer to and build upon existing and comparable concepts, and how NBS relate to sustainability in general. Secondly, we identify how NBS relate to cross-disciplinary research and implementation challenges and present a framework that can aid implementation of interventions intended to work with nature in order to tackle societal challenges. We end by reflecting on the added value of the NBS concept, the opportunities and challenges that it offers to natural resource and ecosystem management, and the role of research.

2. The conceptual context of nature-based solutions

2.1. Differences and similarities with other concepts used for ecosystem management

The NBS concept aims to explicitly link positive outcomes for society (‘solutions’) with a notion of ‘nature’ as something helpful for these aims. It may, therefore, relate to or overlap with other concepts defined and used to inform ecosystem management for societal benefit, although these relationships are seldom acknowledged explicitly (see European Commission, 2015c). Six such concepts with associated definitions, objectives and examples are analysed in Table 2. We have focussed on those most commonly used in contemporary literature about ecosystem management for sustainability, societal benefit and human well-being. None of them has a single uncontested definition, but they are commonly in use within science, policy and practice.

Table 1
Definitions for the concept of nature-based solutions.

	International Union for Conservation of Nature	European Union Directorate General on Research and Innovation
Definition/rationale	<p>'the potential power of nature and the solutions it can provide to global challenges in fields such as climate change, food security, social and economic development' (p. 1)</p> <p>'Healthy, diverse and well managed ecosystems lay the foundation for practical, nature-based solutions to global problems.' (page 16)</p> <p>'[Nature-Based Solutions] offer unique and effective solutions to climate change.... The underlying approach is a pro-active application of the sustainable management and conservation of natural resources to address major global challenges (food security, disaster risk reduction, economy).' (Annex 1, p. 24–25)</p> <p>'The following principles are an initial attempt to provide some guidance on what type of interventions could (or should not) be considered as a nature-based solution.</p> <ol style="list-style-type: none"> 1. The intervention delivers an effective solution to a major global challenge using nature 2. The intervention provides biodiversity benefits in terms of diverse, well-managed ecosystems 3. The intervention is cost effective relative to other solutions 4. The rationale behind the intervention can be easily and compellingly communicated 5. The intervention can be measured, verified and replicated 6. The intervention respects and reinforces communities' rights over natural resources 7. The intervention harnesses both public and private sources of funding' (Annex 1, p. 24–25). 	<p>'Nature-Based Solutions harness the power and sophistication of nature to turn environmental, social and economic challenges into innovation opportunities.' (p. 2)</p> <p>'[Nature-Based Solutions] are actions inspired by, supported by or copied from nature; both using and enhancing existing solutions to challenges, as well as exploring more novel solutions, for example, mimicking how non-human organisms and communities cope with environmental extremes. Nature-Based Solutions use the features and complex system processes of nature, such as its ability to store carbon and regulate water flows...' (p. 24)</p>
Aim of employing concept	<p>'Nature-Based Solutions offer multiple benefits simultaneously and therefore efficiently. This Programme Area focuses initially on nature-based solutions to climate change (including disaster risk reduction), food security, and economic and social development, but will ...explore opportunities to broaden this approach to sectors such as health and access to energy' (p. 5)</p> <p>'Healthy and restored ecosystems make cost-effective contributions to meeting global challenges of climate change, food security and economic and social development' (Table 1, p. 7).</p> <p>'Apart from providing effective solutions to major global challenges, nature-based solutions also deliver clear biodiversity benefits in terms of diverse, well-managed and functioning ecosystems. They must be cost efficient relative to other solutions. As nature-based solutions are designed to reach beyond the conservation community they need to be easily and compellingly communicated as well as being measurable, verifiable and replicable. Finally they must be designed and implemented in such a way as to respect and reinforce communities' rights over natural resources.' (p. 16)</p> <p>'helping the conservation community reach beyond its traditional constituencies, build new alliances and broaden its messaging beyond the immediate imperatives of addressing biodiversity threats' (p. 24)</p>	<p>'Nature-Based Solutions aim to help societies address a variety of environmental, social and economic challenges in sustainable ways.' (p. 24)</p> <p>'...in order to achieve desired outcomes, such as reduced disaster risk and an environment that improves human well-being and socially inclusive green growth (p. 24).</p> <p>'Four principal goals have been identified that can be addressed by nature-based solutions:</p> <ol style="list-style-type: none"> 1. Enhancing sustainable urbanisation... can stimulate economic growth as well as improving the environment, making cities more attractive, and enhancing human well-being. 2. Restoring degraded ecosystems... can improve the resilience of ecosystems, enabling them to deliver vital ecosystem services and also to meet other societal challenges. 3. Developing climate change adaptation and mitigation...can provide more resilient responses and enhance the storage of carbon. 4. Improving risk management and resilience...can lead to greater benefits than conventional methods and offer synergies in reducing multiple risks.' (p. 4) <p>NBS solutions to strengthen community cohesion, involvement of society, with the aim of re-connecting people with nature. (p. 21)</p>
Reference	IUCN, 2012. The IUCN Global Programme 2013–16, Adopted by the IUCN World Conservation Congress, September 2012.	European Commission 2015. Towards an EU Research and Innovation policy agenda for Nature-Based Solutions & Re-Naturing Cities. Final Report of the Horizon 2020 Expert Group on 'Nature-Based Solutions' and Re-Naturing Cities. Directorate-General for Research and Innovation,

Ecological Engineering and Catchment Systems Engineering (including ecological restoration), and Green/Blue Infrastructure (Table 2, columns 1 and 2 respectively) represent targeted approaches for solving specific activity or land-use problems. Encompassing a variety of activities and interventions, they clearly seek to apply natural alternatives to complement technology-based infrastructure and hence can be seen as NBS applications. For example, catchment systems engineering can help to reduce flood risk by attenuating runoff within a catchment (e.g. working with natural processes through the creation/restoration of ponds, wetlands, leaky barriers) thereby providing other multiple benefits (e.g. improving diffuse pollution) (Wilkinson et al., 2014). The difference between the approaches is the notion that NBS are explicitly considered as alternatives to and choices against human-made infrastructure that require large investment in materials and energy.

The concepts of Ecosystem Approach (EA) and Ecosystem-Based Adaptation (EBA) (Table 2, columns 3 and 4 respectively) are also approaches that seek to manage the natural environment in a way that balances benefits for nature and society. In contrast to the first

two concepts, EA and EBA incorporate a systemic approach to understanding those relationships. Greater emphasis is thus placed on ecosystem complexity, change and resilience. The need to decentralise and involve stakeholders is also integral, highlighting the importance of considering different interests and conflicts (Waylen et al., 2014). This emphasis on an inclusive or participatory approach is not always shared by other concepts.

The final columns of Table 2 describe two interrelated concepts thought to have relevance to decision-making, particularly in the face of multiple and potentially competing priorities and aspirations. Ecosystem Services (ES, column 5) describe how society depends on nature (MA, 2005). So far, many studies of ecosystem services still tend to focus on only a single or few services (Abson et al., 2014), although disclosing multi-functionality and multiple benefits is at the core of the ES approach. The concept of Natural Capital (NC, column 6) uses the terminology of 'capital' that is sometimes associated with economy and business, and considers the stock of assets from which ecosystem services flow (Gómez-Baggethun et al., 2010; Schröter et al., 2012). ES and NC

Table 2
Non-exhaustive overview of different concepts related to nature-based solutions.

	Problem solving techniques		Approaches to management			
Concept	Ecological Engineering (EE) and Catchment Systems Engineering (CSE)	Green/Blue Infrastructure (GI/BI)	Ecosystem Approach (EA)	Ecosystem-based Adaptation//Mitigation (EBA)	Ecosystem Services Approach/Framework (ES)	Natural Capital (NC)
Definition	<p>The earliest definition of Ecological Engineering came from Odum, with 'those cases in which the energy supplied by man is small relative to the natural sources, but sufficient to produce large effects in the resulting patterns and processes' (Odum, 1962, as cited in Mitsch and Jørgensen, 2004, p. 25). It has since been redefined as 'the design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both (Mitsch and Jørgensen, 1989, p. 365).</p> <p>It has also been defined as 'actions using and/or acting for nature' (Rey et al., 2015 p. 1336). CSE developed by Quinn et al. (2010), is defined as 'an interventionist approach to altering the catchment scale runoff regime and nutrient dynamics through the manipulation of hydrological flow pathways to manage water quality and quantity sustainably' (Wilkinson et al., 2014) p. 1247). In an even broader context, the concept and practice of ecological restoration can be linked here as well (Aronson et al., 2007).</p>	<p>'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 sand other aquatic ecosystems' (European Commission, 2013a, p. 3). Green infrastructure (land-based) can include, terrestrial protected areas, field margins in intensive agricultural land, ecoducts and tunnels for animals, parks and green roofs in cities. Blue infrastructure (water related) includes coastal areas, rivers, lakes, wetlands but also designed elements such as artificial channels, ponds, water reservoirs, retention basins and tanks as well as urban waste water networks (CEEWEB and ECNC, 2013; European Commission, 2013b; Haase, 2015; Naumann et al., 2010).</p>	<p>A strategy for decentralised, participatory and systemic natural resource management. 'It is based on the application of appropriate scientific methodologies focused on levels of biological organization which encompass the essential processes, functions and interactions among organisms and their environment. It recognizes that humans, with their cultural diversity, are an integral component of ecosystems. It is implemented via 12 principles that are "complementary and interlinked" (UNEP/CBD, 2000); section B, paragraph 6), that include:</p> <ol style="list-style-type: none"> 1) The objectives of management of land, water and living resources are a matter of societal choice. 3) Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems. 5) Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach. 6) Ecosystems must be managed within the limits of their functioning. 7) The ecosystem approach should be undertaken at the appropriate spatial and temporal scales. 9) Management must recognize the change is inevitable. 	<p>'The adaptation policies and measures that take into account the role of ecosystem services in reducing the vulnerability of society to climate change, in a multi-sectoral and multi-scale approach. EBA involves national and regional governments, local communities, private companies and NGOs in addressing the different pressures on ecosystem services, including land use change and climate change, and managing ecosystems to increase the resilience of people and economic sectors to climate change' (Vignola et al., 2009, p. 692).</p>	<p>An approach to understand how natural systems can benefit humans, by 'linkages between ecosystem structures and process functioning and consequent outcomes which lead directly or indirectly to valued human welfare benefits (gains or losses)' (Turner and Daily, 2008, p. 27). These goods and services provided by ecosystems are 'Ecosystem services (ESs)'. They include provisioning services (e.g. food, water, heating and building material from ecosystems), cultural services (e.g. possibilities for recreation, tourism, education, sense of place), regulatory services (e.g. protection against flood or erosion, climate regulation) and supporting services (e.g. soil formation or nutrient cycling) (Alcamo et al., 2003; MA, 2005). If natural capital is the stock of assets, ecosystem services are the flows of benefits derived from those assets (Daily et al., 2011).</p>	<p>Natural capital is the stock of living and non-living parts of the natural system that directly and indirectly yield benefits to humans. Definitions vary in their scope and focus (Wackernagel and Rees, 1997): e.g. Daily et al. (2011, p. 3) define 'living natural capital' as 'Earth's lands and waters and their biodiversity' whilst other definitions include geological and biophysical components (e.g. (Natural Capital Coalition, 2016) or may explicitly encompass interactions and processes that form natural systems (Natural Capital Initiative, 2016). Definitions usually include both renewable and non-renewable resources (Daly and Farley, 2011). Costanza et al. (1998) also include the information stored in natural systems. Some scholars (e.g. Berkes and Folke, 1992) consider the services provided by the natural system as part of the stock as well, but this is normally separated.</p>

Aim of employing concept	<p>'The defined strategies are designed to mimic or to adapt the natural functioning of ecosystems to reach a target ecosystem, within an overall goal of sustainable development and with minimal and preferably biological and/or endogenous inputs' (Rey et al., 2015). CSE seeks first to describe catchment function (or role) as the principal driver for evaluating how it should be managed in the future (Wilkinson et al., 2014). The term 'systems' in CSE relates to both the natural and human functioning of a catchment as ultimately the stakeholders must agree with the interventions proposed (Wilkinson et al., 2014).</p>	<p>To provide '...ecological, economic and social benefits through natural solutions. It helps us to understand the value of the benefits that nature provides to human society and to mobilise investments to sustain and enhance them. It also helps avoid relying on infrastructure that is expensive to build when nature can often provide cheaper, more durable solutions.' (European Commission, 2013b p. 2). It aims to naturally regulate storm flows, flood risk water, air, temperatures, greenhouse gases, and ecosystem quality.</p>	<p>The aim of EA under the CBD is to 'promote conservation and sustainable use in an equitable way' (UNEP/CBD, 2000; Section A, Paragraph 1). It is expected that this concept can guide and enable fair management of natural resources in order to reflect and sustain different needs and values. It notes that conservation and use are to be balanced, and highlights that the objectives for management will vary between different groups and so require societal choice (Waylen et al., 2014).</p>	<p>It is expected that EBA will reduce society's vulnerability to climate change (Vignola et al., 2009).</p>	<p>It is expected that using ecosystem services to understand and describe how nature benefits humans, will help to inform and improve social and political processes so as to improve the management and governance of ecosystems (Primmer et al., 2015).</p>	<p>By enabling natural systems to be valued and managed equally to other forms of capital (financial, human, social, manufactured) (Natural Capital Initiative, 2016) it is expected that considering natural capital can help to improve decision-making for various sectors, including businesses - leading to more sustainable business models that are resilient, efficient, and secure (Natural Capital Coalition, 2016) - but also policy and other sectors.</p>
Example	<p>Vegetation has been used to mitigate hillslope instability, thus reducing several ecological and human problems (Stokes et al., 2014). Belford Catchment, UK uses a range of different natural flood risk management measures to reduce flood risk whilst delivering multiple benefits, UK (Wilkinson et al., 2014; Wilkinson et al., 2010).</p>	<p>Scheldt Estuary, Belgium uses a natural wetland to absorb and slow the flow of heavy rainfall, so reducing flood risks (Morris, 2007). Climate change adaptation in the city of London (Jones and Somper, 2014).</p>	<p>Multi-stakeholder systemic management of the Thanet Natura 2000 site, Kent, UK (Pound, 2008).</p>	<p>Durban's Municipal Climate Protection Programme (Roberts et al., 2012).</p>	<p>Planning for protected areas management under the ecosystem services framework in Doñana, Spain (Palomo et al., 2011). Planners in Vitoria-Gasteiz, Spain restored a river ecosystem along one of the city's main urban arteries, improving the city's sewage system and enhancing the city's ecological resilience. This river restoration will both slow storm water flows and prevent clean rainwater from entering the sewage system (Kopperoinen et al., 2014).</p>	<p>The Puma company's environmental profit and loss accounting system (PUMA SE, 2011).</p>
Potential relation to NBS	<p>CSE is a version of NBS: both are focusing on tackling societal challenges but CSE specifically focuses on catchment-scale working and manipulating hydrological processes in order to benefit humans.</p>	<p>Similar to NBS in some areas and can sometimes be synonymous though differences between "infrastructure" vs. "solution".</p>	<p>EBA aims to balance conservation and management for human needs. It is not equivalent to NBS, but its principles can be used in the design of NBS to improve the range of stakeholders engaged and to balance different interests.</p>	<p>EBA should be part of NBS, to ensure solutions are climate-adapted.</p>	<p>ES concepts can be an excellent way to consider solutions during NBS design and appraisal; however, their use should not be restricted to single or few ES and their beneficiaries.</p>	<p>The NC concept can help demonstrate the role of nature in meeting human needs, and hence the value of considering NBS versus other types of interventions.</p>

are both helpful for illustrating that the variety of goods and services generated by ecosystems (Mulder et al., 2015) depends on how natural systems are protected and managed. However, it can be challenging to actually use these concepts to support decisions (de Groot et al., 2010; Hails and Ormerod, 2013; Hauck et al., 2013; Martinez-Harms et al., 2015).

The four management concepts (columns 1–4) vary along a gradient of whether they take either a reductionist approach or a more holistic one, open to multiple objectives, issues and interactions. They also differ in focus. Furthermore, ecological engineering solutions tend to focus more on human-led physical interventions aided by technology to achieve specific targets. However, regardless of problem framing, it must be recognised that NBS will always be intervening in complex socio-ecological systems and indeed many prior studies have identified the problems of approaches that are based on overly reductionist or narrow processes (Mazzocchi, 2008). It is therefore essential to describe a problem for NBS in terms of multiple perspectives that account for the various links within and between ecological and social systems (Angelstam et al., 2013), and to consider the multiple social and environmental consequences of any intervention. Even in Europe, this is still not regularly the case. For example, the rehabilitation of wetland for flood protection might have positive impacts on multiple ecosystem services such as climate regulation, water purification, provision of habitats and ecotourism, but may at the same time involve trade-offs, with negative impacts on local farming livelihoods. Existing concepts such as ecosystem services could thereby usefully inform NBS, potentially providing a common currency for evaluating the consequences of differing solutions. Previous and current experiences of using all these concepts can assist in understanding the opportunities and challenges for NBS, whilst the NBS concept can connect useful insights from each. Experiences from the efforts to apply and implement these existing concepts, together with insights from Sections 2.2 and 2.3 therefore inform the priorities and challenges we present in Section 3.

2.2. NBS and sustainability

Like many concepts, NBS makes an explicit link to the pillars of sustainable development, putting social, environmental and economic dimensions, at least conceptually, at the same level of importance. In Europe, there has been a strong emphasis on the role of NBS in fostering innovation in an environmental market 'to position Europe as a world leader, both in Research & Innovation on nature-based solutions and in the global market for nature-based solutions' (European Commission, 2015c, p. 6). This could be problematic if understood narrowly in terms of market driven approaches and cash flows. Enhanced capacity to understand, intervene in and manage multiple objectives in complex socio-ecological systems could, on the other hand, offer new opportunities to tackle cross-cutting societal challenges.

The NBS concept does not explicitly address whether the conservation and protection of biodiversity is a goal or simply a prerequisite or basis for NBS. Both views are possible (e.g. as mentioned in the formulation of NBS by the European Commission, 2015c). However, in general NBS appear to be focused on managing and providing multiple ecosystem services at intermediate levels of human use intensity (Schneiders et al., 2012), rather than at actions exclusively directed towards biodiversity conservation. If NBS are also intended to conserve biodiversity and ecosystems, this requires explicit articulation and stronger recognition in NBS projects. These issues relate to the notion of 'strong' versus 'weak' sustainability: whilst weak sustainability allows the substitution of different forms of capital (man-made or technological, human, social, natural), strong sustainability underlines the primary role of natural capital in sustaining human life, and does not present natural capital as totally substitutable (Neumayer, 2003).

Lastly, the terminology of 'solutions' can lead to assumptions that problems and needs are clear and agreed. However, as many issues

pertaining to biodiversity and ecosystem management are complex, there may not even be an agreement about the problems to be solved, let alone the type of solutions needed (Game et al., 2014). For these reasons, there is a need to better recognize connections within and between societies and ecosystems, but also to accept uncertainty. Reflection, dialogue and democratic negotiation about the notions of sustainability and NBS is essential to safeguard socio-environmental justice (Ekins et al., 2003). To achieve this, examples and principles are available from attempts to implement other concepts such as the Ecosystem Approach. This is essential to allow social and environmental sustainability to be achieved. It will also allow social (and social-ecological) innovation to be fostered, which is one of the desired components within most formulations of NBS (United Nations, 2016).

2.3. The challenges of NBS as a new umbrella concept for biodiversity and ecosystem stewardship

A central challenge for an 'umbrella concept' like NBS and other frameworks is where to draw the line as to what is considered as 'nature' or 'natural'. Many interventions may involve specific uses or manipulations of organisms and ecosystem processes; hence requiring decisions about acceptable levels of human intervention. For example, are genetically modified organisms or biomimicry developments considered as NBS? Additionally, there is potentially a multitude of solutions that could use nature, ranging from small scale land management to ecosystem restoration, the greening of artificial surfaces like green rooftops or green walls in cities, or broad-scale climate change mitigation and adaptation measures such as afforestation, natural flood control and, potentially, geoengineering. The definition provided by the European Commission (e.g. 2015) encompasses most of the above-mentioned examples, except those that "artificially alter nature, such as genetically modified organisms" (p. 24). The existence of a variety of ways to frame and define the concept is not necessarily problematic, as long as each case makes explicit its rationale and particular interpretation of NBS. Engaging in pluralistic reflection about alternative framings and conceptualizations can in itself be useful for identifying what is meant by NBS and the expectations for 'solutions' in any particular context.

There are several aspects of the NBS design process that can help to define what makes NBS sustainable, and why. Below we present these as questions. These can provide a logical approach to distinguishing unwanted or even potentially harmful aspects of the 'solutions' chosen.

- The range and nature of the problems to be 'solved' need specification on a case-by-case basis: Are the problems transient or persistent? By which communities and/or stakeholders are they mainly experienced? What are the qualities of the problems that have particular implications for finding solutions?
- Framing of nature is challenging: Is biotic nature only or at least primarily meant, or are abiotic (bio-physical, chemical) ecosystem components and processes included? Is nature/are ecosystems taken as a whole, including for example water, matter and energy cycles as well as landscapes and urban environments with artificial structures and humans? And, is self-regulatory potential considered an aspect of naturalness and sustainability?
- Most NBS will likely include some degree of alteration and/or 'design' of nature (e.g., trade-offs by favouring/choosing one ecosystem service over another, by selecting certain assemblies of species); what is the level of integrity or 'naturalness' in order to still be considered a NBS?
- Is it possible to consider all the possible pros and cons of an intervention? Is it important to consider both benefits and costs in detail? For example, in relation to human health, NBS may bring multiple health benefits (Hartig et al., 2014), but may also contribute to health risks, such as allergies and infectious diseases (Keune et al., 2013).
- How does the 'solution' deal with the complexity of problems, as

systemic problems with multiple trade-offs cannot be easily broken down to 'easy' solutions?

- Do 'solutions' rely on technical/physical types of innovation, and to what extent are intellectual and social innovations considered? The common use of terms such as 'cost-effectiveness' or 'innovation' (often perceived as technological) might indicate a preference for the former, but a combination will have more chances of contributing to sustainability (see also discussion on 'innovation' in van den Hove et al. (2012)).
- How can NBS ensure that all relevant stakeholders are considered and democratically involved, taking into account social cohesion and equity? How can conflicting goals and interests be reconciled when creating and choosing options for NBS? How can any differing outcomes of NBS be anticipated and evaluated, and how can fairness be judged?

Many aspects of these questions also arise when using other existing concepts, see for example the controversies about the role and application of the ecosystem services concept (Fitter, 2013; Gómez-Baggethun and Muradian, 2015; Silvertown, 2015). However, the ostensible focus of NBS on the 'solutions' domain may help to tackle some challenges, by explicitly focusing attention on the actions and inputs needed.

For the practical implementation of NBS, we suggest use of these questions together with a core framework of elements discussed in the following section. These elements provide guidance to stimulate the exploration of new pathways to tackle societal challenges, yet allow the scope of NBS to be clearly bounded for different areas (Eggermont et al., 2015; Maes and Jacobs, 2015). Science, policy and practice groups will be needed to tackle these challenges. Research scientists would especially need to develop a new role to support this framework, based on transdisciplinarity and a systemic approach to problem solving and management. In the following section, we present the elements we consider relevant for enabling effective and equitable development of NBS. For example, the rehabilitation of wetland for flood protection might have positive impacts on multiple ecosystem services such as climate regulation, water purification, provision of habitats and ecotourism, but may at the same time involve trade-offs, with negative impacts on local farming livelihoods.

3. Nature-based solutions in practice: key elements for the operationalization of the NBS concept

As with all other concepts, NBS will need to be embedded in the existing policy mix including biodiversity protection measures, spatial planning, environmental assessment or economic incentives, as well as in practical applications and trials (Barton et al., 2014). At the same time, the institutional context will need to evolve to enable the necessary shifts to take place (Maes and Jacobs, 2015). In most cases, the critical decisions about NBS design, costs, location and scale as well as levels of management intensity will involve a wide range of stakeholders who may have different ideas and pre-existing ways of managing their problems. Further, NBS will have to become accepted alternatives to other solutions, which may not be nature-based or may be unsustainable. For this, we consider the five steps described in Sections 3.1 through 3.5 as key elements to be addressed in NBS projects, jointly by researchers and other actors (Fig. 1 – designing NBS projects, see also Cohen-Schacham et al. (2016)). We include examples from current literature for illustration and make use of the main elements identified in transdisciplinary research and successful practice in general (e.g., Jahn et al., 2012).

3.1. Dealing with uncertainty and complexity: the adaptive management approach as an example

Uncertainty will be a prevailing characteristic when designing NBS, given that in many cases NBS deal with complex socio-ecological

systems whose responses to management and natural factors are often non-linear, heterogeneous and incompletely known (Seastedt et al., 2008; Suding et al., 2004). One way of coping with uncertainty, and limiting the risks of triggering negative responses, is to manage for increased resilience (Lindenmayer et al., 2008). Some of these practices are incorporated in adaptive management, which is an approach recommended for dealing with uncertainty, complexity and dynamics. It includes devising flexible ways to maximize learning opportunities by applying different strategies, and the consideration of practices as experiments by ensuring that management treatments are replicated and responses are carefully monitored (Assmuth and Hildén, 2008; Assmuth et al., 2010; Lindenmayer et al., 2008). Although adaptive management has proven difficult in practice (Roe et al., 2005; Westgate et al., 2013); the broad experience gathered so far would help to support effective NBS implementation.

Adaptive management that includes structured monitoring of ecological responses is rarely implemented (Lindenmayer et al., 2008); which reflects the challenges and costs of such endeavours. However, there are several models developed for planning and management of, for instance, protected areas and other demarcated nature areas, such as Recreation Opportunity Spectrum, Limits of Acceptable Change, Visitor Impact Management, and Visitor Experience and Resource Protection (Newsome et al., 2012). These can all be characterized by their use of adaptive management, where goals and actions are adapted to ongoing changes (ecological and social). Such operational models, also abound in other areas of ecosystem and natural resource use, often include socio-economic perspectives, and as such could feed into the development and application of NBS. The development of an evidence-base that holds details of the circumstances in which NBS work is an essential component of effective adaptive management (see below).

Adaptive management should be coupled with some description of the critical dimensions of the solution, including societal factors. This would ensure that NBS would not only function in ecological terms but would also avoid that they are economically unfeasible or socially untenable. In some cases, social factors can be incorporated by simply placing ecological entities and processes in a societal context, in others, when feasible and relevant, through more detailed and explicit analysis of the socio-ecological links. In both cases, socio-ecological modelling can be part of a transdisciplinary learning process, where approaches to problems and solutions, including values and goals, are deliberated by experts, practitioners and stakeholders, and adapted where and when needed (cf. Sections 3.2 and 3.5). Such an approach can yield important opportunities for citizen participation and can result in the inclusion of local knowledge, environmental justice and local economic growth and an increased understanding of uncertainties and complexities (Irvine and Kaplan, 2001).

3.2. Ensuring the involvement of multiple stakeholders

Any societal problem or issue is likely to be affected by or have effects on several groups of stakeholders. Their involvement is thought to bring three types of benefit to the process of planning and delivering improvements in environmental management (Blackstock and Richards, 2007): (i) 'substantive' benefits, as stakeholders' perspectives, conditions and knowledge inform and improve planning (van den Hove, 2000); (ii) 'instrumental' benefits, as the process becomes better understood and more acceptable to stakeholders, and hence better supported (Parkins and Mitchell, 2005); and (iii) 'normative' benefits, as stakeholder involvement increases the legitimacy of the process, and generally supports democracy (Schultz et al., 2010). These benefits could be translated into the design of NBS, but require that stakeholders are meaningfully involved and empowered through the NBS process (e.g., Waylen et al., 2015a; Wyborn, 2015).

The participative process may be more or less complex depending on the issues to be considered. In particular with NBS that would involve important trade-offs (see Section 3.5) a participatory process becomes

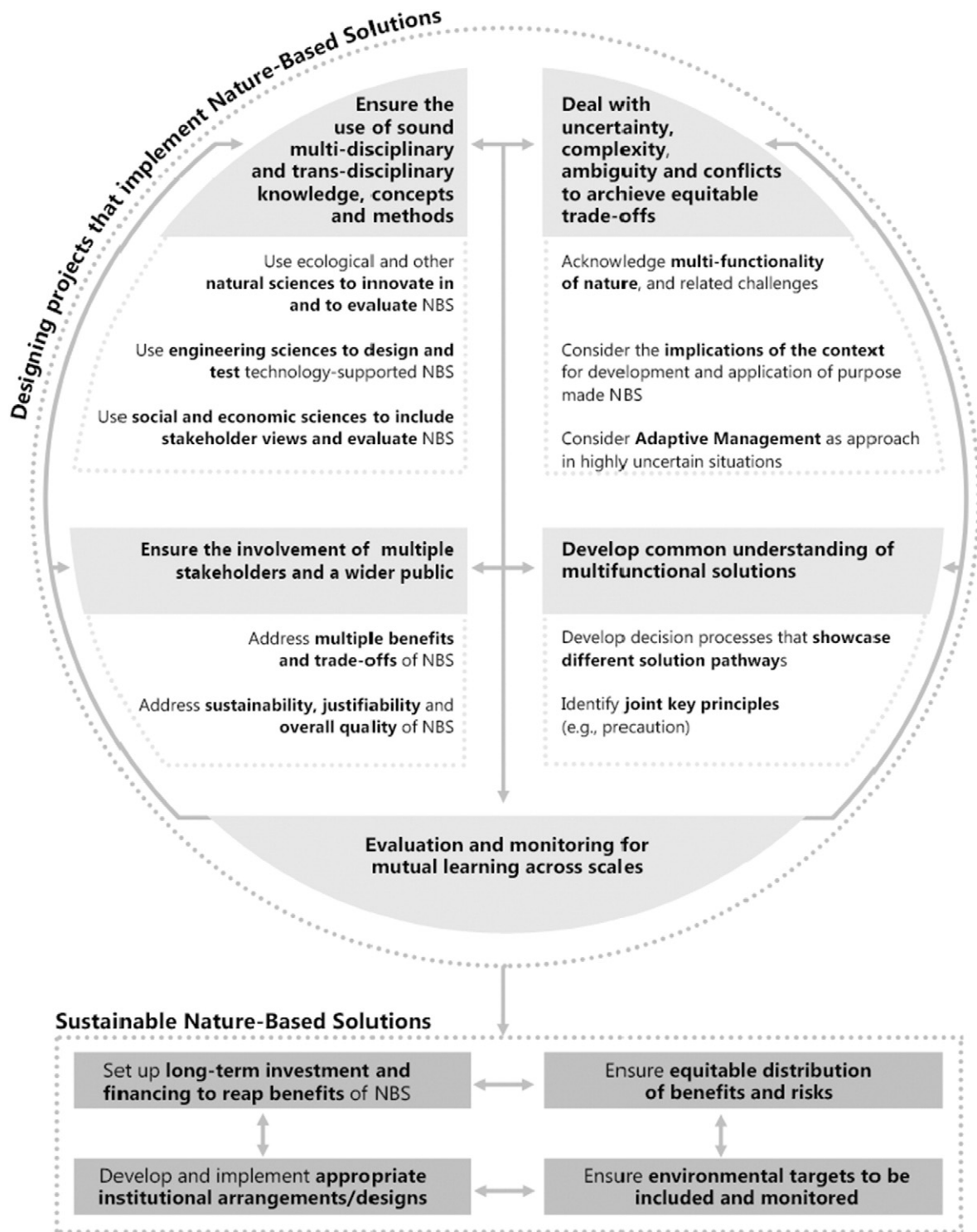


Fig. 1. Processes and dynamics in designing and implementing nature-based solutions, including multidisciplinary and transdisciplinary knowledge creation and use to achieve successful solutions balancing economic, social and ecological targets.

critical, and can be especially pertinent, when their aim is to better connect people with their local natural resources. There is now much guidance and many ideas about how to facilitate collaborative efforts and engage relevant stakeholders, for example via analytical-deliberative approaches (Fish, 2011; Keune and Dendoncker, 2013). These approaches can be demanding in terms of time and skills, but can ensure co-design, innovation, ownership and later stewardship of NBS (Armitage et al., 2007; Jones-Walters and Çil, 2011; Reed, 2008). Finally,

stakeholder engagement is also relevant for sharing of knowledge and learning across and between cases (Keune et al., 2015).

3.3. Ensuring the sound use of multi- and transdisciplinary knowledge

NBS projects will need to be combined with an increase of interdisciplinary work across scientific domains. We see this as an endeavour that goes beyond the collaboration that presently takes place, for

example, between ecological sciences and engineering in many restoration projects, or when ecological and social sciences jointly address the use of ecosystem services. There is a strong basis for such collaboration due to the many integrative research activities that have taken place in the past, but NBS projects are likely to increase the demands for input and flexibility from different disciplines.

As society will necessarily shape the design, selection, implementation and consequences of NBS, social sciences can help us to understand the potential and pitfalls of NBS to inform the design of new NBS, and to improve our general understanding of environmental governance. Social science research can provide insights into how different choices may affect support for and implementation of NBS, about how to foster stakeholder deliberation and empowerment (e.g. Reed, 2008), and the identification of relevant, shared social values (Kenter et al., 2014) and collective actions. Some of this expertise is derived from studies of existing related approaches (Table 2). For example, the field of ecosystem services has advanced in relation to the development of methods to address the challenge of economic externalities that may occur when exploiting natural resources (e.g. via Payments for Ecosystem Services projects such as those described by Caro-Borrero et al. (2015)). However, it also embraces the assessment of multiple and non-monetary benefits from nature (Díaz et al., 2015), indicating that experience about this and other methods to elicit motivation for choices should also be considered for promoting change (Santangeli et al., 2016). Existing governance structures and institutional processes will also affect this issue, and may foster or hinder the search for alternative NBS, their acceptance and ultimate success. The need to adapt governance structures must also therefore be taken into account (Rauschmayer and Wittmer, 2006; Vignola et al., 2013; Waylen et al., 2015b).

There is also a continuing need for NBS to be knowledge-based in terms of ecological functioning. Despite the wealth of available ecological knowledge, there are still considerable gaps in translating it into actions that can help to design sustainable systems as an integral part of biodiversity and natural resource management (MA, 2005). There are presently major challenges in relation to the European MAES - Mapping and Assessing Ecosystem Services project which has set out to map and evaluate ecosystem services in terms of their condition and functionality and for the Natural Capital Accounting (NCA) project, precisely at the link between ecological research and economics (Maes et al., 2013). The gaps in knowledge are often still of a fundamental character and need to be addressed in order to inform future NBS projects.

Furthermore, there is a reverse flow of knowledge from practical action to science, guiding the formulation of new, even fundamental questions and of answers to them. Ecology and related disciplines need to provide up-to-date and broader conceptual frameworks (Suding et al., 2004) and effective practical tools (Hobbs and Harris, 2001) to support this two-way flow. Ecological disturbance, ecosystem dynamics and tipping points, population viability, vegetation structural diversity, the role of keystone species and functional groups, response diversity (Zang et al., 2014) and landscape connectivity are considered to be critical features that underpin the persistence of ecological functions and the responses of ecosystems to climate change, disturbances and environmental variability (Lavorel et al., 2015). In addition, ecological models that show the possible outcomes of human interventions would be useful tools for planning NBS (for example the European Commission's NCA).

The representation of the ecological system can be at different degrees of complexity, quantitative or conceptual, but it has to capture the essence of the system and its dynamics in order to address the problem at hand; which argues for the use of ecological knowledge from as many sources as possible, including that from practitioners and the local experience. The collection of data on the ecological aspects before and after NBS implementation, together with information on the actual NBS measures taken as well as related socio-economic parameters, forms a fundamental component of any evidence-based on NBS (see also Section 3.5).

3.4. Developing common understanding of multifunctional solutions, trade-offs and natural adaptation

The involvement of relevant actors and a responsive use of natural and social sciences as outlined will allow NBS to set their goals based on a common understanding of the available options, their relative costs as well as social and ecological impacts (Fig. 1). This is challenging as the direct and indirect impacts will often be uncertain and may take time before they become evident, and the estimates of both impacts and costs will be dependent on value judgments. The understanding of them is therefore provisional, but helps to create informed and transparent processes for developing and applying NBS.

Implementing the NBS concept implies the fulfilment of multiple goals. Ideally, clear win-win options can be found, but trade-offs between alternative forms of using nature are ubiquitous (Barton et al., 2014), and cannot be solved through exact calculus and utility maximization. This is also due to incomplete knowledge (see Section 3.3) and conflicting value attributions. Instead, they require other kinds of approach, such as qualitative, multi-criteria, iterative and experimental, particularly in line with adaptive management (Prato, 2007; see also Section 3.1). In addition, NBS projects will face situations where several options can be appropriate for a particular site, catchment or region, each of them with different associated costs, benefits, impacts and risks (Eggermont et al., 2015) and involving different levels of conflict over the use of space (Schindler et al., 2014). Specifically, maintaining ecosystem and landscape-level ecological functions often implies hard trade-offs with other land use options, including provisioning ecosystem services (Schröter et al., 2014). NBS will need to address such trade-offs and set goals that maintain or restore ecological structures and functions based on best available knowledge and on an agreement regarding the impacts, securing compatibility with the level of use and disturbance.

Complexity in ecosystem responses presents considerable challenges in terms of setting objectives, selecting the appropriate solution and setting quality standards. It requires flexible and transparent models of key structures and processes that can gather the best possible knowledge from science and practice, that are flexible enough to incorporate new knowledge (for instance acquired in a process of adaptive management and which combine evidence with precaution) and that make uncertainty explicit (Rumpff et al., 2011). This however raises the important question of how to maintain natural adaptability when designing NBS, specifically how to adjust ecosystem structure, process and function in response to natural and human disturbance. This can be achieved for instance, by incorporating ranges of desired or accepted variability in the formulation of NBS goals, by ensuring that the means for planning and implementation of NBS are adaptable, by focusing on ecosystem processes in addition to composition, by prioritizing native species and local resources, and by following-up and acting on changes in ecosystems, technologies and in society.

If this is achieved, NBS will foster the transformation in the ecosystem management paradigm, which is to replace the increase-efficiency and single-objective management (e.g., separating conservation, land use and water issues), with strategies that build on maintaining ecological resilience taking into account the multi-functionality of landscapes and ecosystems (Hansen and Pauleit, 2014; Schindler et al., 2014).

3.5. Evaluate and monitor for mutual learning

A final important element that is often raised in biodiversity conservation and ecological restoration practice, and which is applicable to NBS, is the development of adequate measures of progress and success towards agreed goals. This often means selection of a set of easily measurable criteria for the ecological, social and economic effectiveness of the interventions (e.g., Heink et al., 2015; Hobbs and Harris, 2001), but which may result in important but less easily measurable ones being neglected.

Many indicators have the potential to be considered as success criteria, but these will need to be clearly related to the specific 'solution' goals in terms of biophysical aspects and ecosystem services (e.g. carbon sequestration, water use efficiency, pollination). The same applies to the economic and social spheres in terms of value, capital or investment/revenue in the system or to the effects on health and well-being. In terms of the above criteria, the outcomes of NBS projects are likely to be better understood over the long-term, especially for NBS that are applied at large scales.

NBS will often deal with problems that manifest at different spatial scales from local to regional, national and even global (e.g. NBS for addressing climate or planetary change such as carbon fixation). When evaluating and monitoring the efficiency and effectiveness of NBS a nested approach across scales is therefore required. Certain local NBS may easily be monitored in a short time-span and in connection with locally specific challenges. The feedback in terms of adapting (management of) such NBS can also occur quickly. When considering larger geographical scales, however, the temporal scale of evaluation will increase as will the specificity of reaching predefined goals. As solutions at various geographical levels are not exclusive, evaluation requires the possibility of upscaling and downscaling monitoring results and coordinated processing and communication across scales.

The social sciences can be helpful here in offering participatory evaluative and co-development approaches, as well as quantitative well-being indicators (e.g., Dallimer et al., 2014). Due to the complexity of nature and societies, dealing with quality criteria for analytical, deliberative, extended peer review or participatory processes is challenging (Keune et al., 2014). Rauschmayer et al. (2009) point out that process outcomes may be valued quite differently from different stakeholder perspectives. To respond adequately, they propose the use of participatory evaluation in order to respect the legitimacy of different views on quality, for example Delphi, group-model building and other expert or stakeholder opinion solicitation and deliberation methods (Sendzimir et al., 2010). Resulting information can sometimes be most relevant for politicians and decision-makers as it provides important contextual information about the human dimension.

4. Summarizing discussion: societal opportunities and challenges of the NBS concept

Like many umbrella concepts, NBS bring new challenges and opportunities from the perspectives of science, policy and practice. Some of the likely challenges to be encountered by NBS will be similar to those encountered by other concepts for managing nature (see Table 2), whilst others may be unique to NBS. Furthermore, there are still uncertainties and knowledge gaps in terms of overlap and delineation associated with linked concepts. For example, stakeholder participation and the adoption of a truly systemic perspective is extremely difficult considering the fuzziness and uncertainties regarding the basic concept. It is therefore important to use all relevant sources of expertise in developing and applying NBS, and to support and share learning within and across NBS projects, depending on their focus. Several attempts have already been outlined that identify such areas (see for example Eggermont et al., 2015; European Commission, 2015c; Cohen-Schacham et al., 2016). For us, the following four areas will allow for a further specification of the elements outlined in Section 3:

- i) the maintenance of biodiversity, ecological functions and/or ecosystem services in systems and at scales where human management interacts with natural processes (ecological engineering, ecosystem approach, ecosystem services management);
- ii) the restoration of ecosystems that have been damaged by human activities (ecological restoration, ecological engineering);
- iii) the design of solutions as a mechanism to cope with climate change and other factors of environmental variability or hazards (ecosystem services management); and,

- iv) the sustainable utilization of nature to contribute to alleviating challenges in human well-being, including vulnerability, social justice, economy and culture (ecosystem services management).

These four focus areas will need different kinds of NBS that complement or include existing approaches within them. For example, activities in i) will need to respect existing instruments for nature protection like protected areas, regulation of use and/or incentives for nature-friendly practices, whereas activities in ii) will often build on/in-clude ecological engineering approaches. Developing this in a transparent manner will be essential if NBS are to have an added value compared to existing approaches.

From a scientific perspective, this calls for a transdisciplinary research approach that links practitioners, policy-makers and scientists from different disciplines, and which engages with citizens and other users and producers of knowledge. Transdisciplinary science is already encouraged in areas such as the EU Horizon 2020 Programme (European Commission, 2015a); furthermore, the EU expects city authorities to lead research on NBS for 'Smart and Sustainable Cities' (European Commission, 2015b) with a link to green growth and eco-innovation. However, transdisciplinary science will bring its own challenges, and is still far from being 'mainstream' (Angelstam et al., 2013; Brandt et al., 2013; Keune et al., 2015). Practical support and guidance will be needed in order to reflect potentials and challenges of cross-sectoral and multi-actor collaboration (Fig. 1). Tackling complex social-environmental problems will often highlight conflicts among different interests or sectors. That creates a major opportunity for the NBS concept to allow and even invite 'outside the box' thinking. However, careful facilitation will be needed for conflicts to be productive in this way (Rauschmayer and Wittmer, 2006).

NBS therefore also offer opportunities for encouraging mainstreaming of environmental targets into sectors in policy, business and practice that might not traditionally consider or value the environment, thereby strengthening the potential for strong sustainability in decision making (Fig. 1). This might be the biggest strength of the NBS concept, but this can also bring the risk of 'overselling nature' (Rodriguez-Labajos and Martinez-Alier, 2013) or of encouraging a perception of ecosystems as entirely-substitutable by other assets used by humans. Long-term investment and financing will need to be set up in order to reap the (equitably distributed) benefits of NBS (Fig. 1). In that sense, NBS can become a major contributor to the wider concept of a 'green economy', which is also critically discussed regarding its sustainability perspective (Brand, 2012; Gasparatos and Willis, 2015). The implementation of NBS projects will therefore need to be embedded in the corresponding societal debates and deliberative processes. As a minimum, communication about NBS should highlight risks from overly-simplistic or optimistic framings (see for example, the 'green revolution' of the 1960s (McIntyre, 2009) or recent discussions of 'eco-gentrification' (Curran and Hamilton, 2012)). Ideally, a diversity of actors should be involved in the deliberative processes (Parkins and Mitchell, 2005) that could take place in relation to the role, scope and appropriateness of interventions premised in relation to NBS. This will also need a careful reflection on institutional arrangements that can enable NBS with such inclusive, long-term and balanced perspectives.

To have the best chance of success, NBS projects should be based on a well-balanced, clear, widely accepted and implementable set of key principles. The considerations set out above can serve as a starting point and a foundation. The IUCN (2012) definition of NBS, (see Table 1, Cohen-Schacham et al., 2016) also provides a reference point, and any rationale should further build on the 12 Malawi principles of the Ecosystem Approach, which has also been applied in a number of European contexts (e.g. Apitz et al., 2006; Waylen et al., 2015a). The principles must allow flexibility to accommodate different types of solutions in the focus areas of NBS, which is crucial for innovation (Eggermont et al., 2015) whilst ensuring that no dimension of

sustainability is overlooked. Developing them in the coming years, including an integrated 'innovation' perspective on NBS will also provide an opportunity to introduce a corresponding framework for evaluation and monitoring (Fig. 1). In order to utilize the potential of NBS for managing risks, the frameworks of the International Council for Risk Governance (IRGC, 2005; IRGC, 2009) for risk governance can be helpful (cf. Klinke and Renn, 2014; Renn and Klinke, 2013).

To conclude, the new NBS concept should be perceived as an opportunity, but also as a challenge since a good understanding of ecosystem processes is needed, a diversity of actors must be engaged and a broad set of societal facts/issues needs to be included and integrated. It is a chance for sustainability science to achieve more recognition in policy, projects and practice, and to bring together ideas from all relevant actors. Key open questions about how to implement NBS will remain as is currently the case for other similar concepts such as adaptive management and the Ecosystem Approach. Whether NBS become something that goes beyond 'just another communication tool' to promote a positive view of 'nature-based' and 'sustainable' management measures, and which avoids using old tools with diverse conceptual foundations, will depend on whether these conceptual and practical challenges can be addressed when developing projects and linking them across scales, contexts and people. Bringing together the diversity of context, societal backdrop and scale will be essential if project funders are to deliver frameworks within which researchers and other actors are to implement genuine, sustainable nature-based solutions.

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