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Urban greening through nature-based solutions – Key characteristics of an emerging concept

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ABSTRACT

As a result of urbanisation and climate change, many cities experience the necessity of efficient and sustainable land use. Nature-Based Solutions (NBS) are interventions that address social, economic and environmental sustainability issues simultaneously, thereby presenting a multifunctional, solution-oriented approach to increasing urban sustainability. As elements of the emerging NBS concept resemble related, existing approaches to urban greening, this review assesses the implications of this concept for discourse and practice in urban greening. The paper identifies key NBS principles and compares them with those of Ecosystem-Based Adaptation (EBA) and Green Infrastructure (GI). Key differences emerge: the NBS concept incorporates a broader array of interventions and a broader range of perspectives on what qualifies as 'nature-based', and it is most explicitly oriented towards providing solutions to complex challenges. NBS implementation could therefore benefit from a more performance-based planning approach; a flexible approach to urban planning which accommodates the integration of multiple land uses and considers urban complexity. We conclude that the NBS concept has potential to unite currently segregated bodies of knowledge generated as part of related approaches to urban greening, and can enable researchers and policymakers to more explicitly discuss the role of nature in addressing a broad range of sustainability challenges.

1. Introduction

Processes of urbanisation and climate change require cities to consider the sustainability of urban land use planning approaches. Urban nature is increasingly envisioned as a potential sustainability solution for urban planning and development (European Commission, 2015; Fink, 2016; ICLEI, 2019; Lafortezza, Chen, van den Bosch, & Randrup, 2018; Maes & Jacobs, 2015). This builds upon a long tradition of exploring the role of nature in urban planning and development, such as garden cities or green belts (Scott et al., 2016; Van Schendelen, 1997). Concepts that are currently used as part of the urban greening lexicon include Green Infrastructure (GI) and Ecosystem-Based Adaptation (EBA). Nature-Based Solutions (NBS) is the latest addition (Nesshöver et al., 2017).

NBS are interventions based on nature that are envisaged to address sustainability challenges such as resource shortages, flood and heat risks and ecosystem degradation caused by processes of urbanisation and climate change. The concept of NBS has emerged over the last few years in transnational – largely Europe-specific – policy discourses on biodiversity and ecosystem services, sustainable urban development, climate change and greening the economy (Balian, Eggermont, & Le Roux, 2014; Faivre, Fritz, Freitas, de Boissezon, & Vandewoestijne, 2017). An opinion piece in Nature recently argued that NBS hold much potential: "the concept it represents is of vital and urgent significance. As the grand challenges that face society continue to build, so does the need for multidisciplinary, evidence-based strategies to, for example, protect water supplies, address habitat loss and mitigate and adapt to climate change" (Nature [editorial] 2017, 134).

However, it is still unclear what defines NBS as a strategy for urban sustainability planning and in which ways it differs from similar concepts aimed at urban greening. For instance, typical examples of NBS such as parks, sustainable flood management systems, or green roofs (Fink, 2016; Haase, 2015; Scott et al., 2016) are elsewhere referred to as EBA (Brink et al., 2016) or GI (Andreucci, 2013; Tzoulas et al., 2007). While notable pioneering work already reflects on NBS and related concepts (e.g. Nesshöver et al., 2017; Pauleit, Zölch, Hansen, & Randrup, 2017), it does not specify yet which characteristics are unique to NBS. Moreover, core principles of NBS need to be articulated more

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clearly to avoid hampered community and policy uptake, misunderstandings and ineffective urban planning and implementation (Escobedo, Giannico, Jim, Sanesi, & Lafortezza, 2018; Nesshöver et al., 2017; Pauleit et al., 2017). Building on earlier comparisons between NBS and related concepts and a review of NBS literature, this paper therefore identifies the characteristics of NBS, while EBA and GI literature is used as a reference to determine to what extent the identified characteristics uniquely apply to the NBS concept. In doing so, we also set out to identify core principles of NBS, i.e. the essential elements of any NBS intervention.

The next section presents a brief introduction of NBS, EBA and GI, including definitions as well as previous reflections on commonalities and differences between these concepts. Section 3 outlines our review methodology. Section 4 outlines the main characteristics of NBS and compares these to EBA and GI characteristics. In Section 5, we identify core principles of the NBS concept and reflect on the implications for planning and governing urban NBS implementation. Section 6 briefly summarizes our findings and concludes.

2. NBS, EBA and GI: a brief introduction

The NBS concept has co-evolved in practice and research. It was originally coined by policy-maker and practitioner networks (in particular via the International Union for Conservation of Nature (IUCN)) in relation to climate change adaptation as well as biodiversity conservation and management, and later reconceptualised by the European Commission to account for social and economic goals more explicitly (Eggermont et al., 2015; Nesshöver et al., 2017). Pioneering work has traced back the origins of the NBS concept to earlier attempts at green space planning or the integration of ecosystem services in urban planning (Escobedo et al., 2018; Fernandes & Guiomar, 2018). However, the evolution of the NBS concept and its links to previous practices of urban planning with nature remain largely implicit.

Definitions of the NBS concept are generally broad and allow for different interpretations (Nesshöver et al., 2017). A definition that has often been referred to is the one by the European Commission (2015, 5), defining NBS as "actions which are inspired by, supported by or copied from nature" with "the aim to help societies address a variety of environmental, social and economic challenges in sustainable ways" (Albert et al., 2019). NBS have also been characterised as "[…] the use of nature in tackling challenges such as climate change, food security, water resources, or disaster risk management, encompassing a wider definition of how to conserve and use biodiversity in a sustainable manner" (Balian et al., 2014). Maes and Jacobs (2015, 123) define NBS as "any transition to a use of ecosystem services with decreased input of non-renewable natural capital and increased investment in renewable natural processes". Lafortezza and Chen (2016) similarly define NBS as the incorporation of ecosystem services into applicable solutions. Albert et al. (2019, 14) define NBS in the context of urban and landscape planning as "actions that (i) alleviate a well-defined societal challenge, (ii) utilize ecosystem processes of spatial, blue and green infrastructure networks, and (iii) are embedded within viable governance or business models for implementation".

The available literature indicates that NBS should be conceived of as an umbrella concept (Nesshöver et al., 2017; Pauleit et al., 2017), which is intended to 'sweep up' all other concepts for sustainability interventions that employ nature, such as ecosystem services, GI, EBA and eco-engineering (Nature [editorial] 2017, 134). Particularly in the case of urban NBS, the concept is often used in similar ways as the concepts of EBA and GI (Kabisch et al., 2016; Pauleit et al., 2017). However, as Pauleit et al. (2017, 43) note, a mere "re-labelling of business as usual" in urban planning harms the understanding and effective use of NBS and previous concepts. This not only reduces opportunities to learn from analyses and evaluations of NBS, but also hinders contributions to the governance and implementation of NBS interventions and to scaling up of interventions (cf. Opdam, Westerink, Vos, & de Vries, 2015; Runhaar, Wilk, Persson, Uittenbroek, & Wamsler, 2017).

The Convention on Biological Diversity (CBD), often referred to in academic discussions of the EBA concept (Brink et al., 2016; Chong, 2014; Dhar & Khirfan, 2016; Wamsler, Luederitz, & Brink, 2014), defines EBA as "the sustainable use of biodiversity and ecosystem services into an overall adaptation strategy to help people to adapt to the adverse effects of climate change [that] can be cost-effective and generate social, economic and cultural co-benefits and contribute to the conservation of biodiversity" (Secretariat of the Convention on Biological Diversity, 2009, 41). GI definitions seem to range widely; some consider it a 'contested concept' (Wright, 2011, 1004) or a 'melting pot' (Hansen & Pauleit, 2014, 516). A definition cited more than once is that of the European Commission (2013, 3; e.g. in Hansen & Pauleit, 2014; Garmendia, Apostolopoulou, Adams, & Bormpoudakis, 2016), characterising GI as a "strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services".

With regard to commonalities and differences between NBS, EBA and GI, Kabisch et al. (2016) indicate that these concepts all represent systemic approaches in which specific interventions are employed to solve sustainability issues. Similarly, the most important commonality between NBS and related concepts identified by Nesshöver et al. (2017) is the explicit correlation between nature and 'positive outcomes' for society. NBS, GI and EBA hold in common that they are embedded in inter- and transdisciplinary research and rely on participatory governance (Pauleit et al., 2017). In addition, all promote the principle of multifunctionality. Pauleit et al. (2017) note that the breadth and vagueness of definitions for each of the concepts make it difficult to clearly delineate differences. Some contrasts do emerge from their comparison, however: they conceptualise EBA and GI as a subset of NBS, while GI focusses less on the role of biodiversity and is less action-oriented than NBS. Moreover, GI may offer guidance on practices to integrate NBS into urban planning. Conversely, Nesshöver et al. (2017) conceptualise GI as an application of NBS with an explicit focus on infrastructure, while EBA is conceptualised as a more systemic approach to manage the natural environment including a specific focus on inclusion and participation. Finally, Kabisch et al. (2016) conceptualise NBS as more innovative than related concepts in the sense that it builds on them but targets urban sustainability issues more explicitly.

3. Methodology

This section first outlines our approach to selecting academic literature, followed by our approach to analysing that literature. Two reasons inform the choice to focus primarily on academic, peer-reviewed publications. The first pertains to the character of our research question: we focus on conceptualisations of NBS and provide an attempt to contrast those to conceptualisations of EBA and GI. Academic literature generally takes a more conceptual angle than policy documents in their use of these terms. Furthermore, academic literature has more systematically documented how different concepts are understood. The second reason is more pragmatic: there is no database on public policy that equals academic literature databases in presenting an overview of municipal, regional or national-level publications on certain topics.

To retrieve relevant papers, we first queried the Scopus database using the search term 'nature-based solutions' (in title, key words or abstract; date of search: 5 April 2019). The search query did not explicitly focus on NBS in cities, in order to allow for exploring how much of the literature actually discusses urban NBS. The search yielded 218 articles, articles in press and review articles. An initial review of materials (of title and abstract) showed that the majority of documents discussed particular types of nature-based interventions and referred to the NBS concept only once or solely used it as an article keyword. These documents were excluded from the review. The 43 items that discussed NBS more substantially were included in the review.

In the material selected for this review, GI and EBA were most often discussed in close relationship with NBS. We therefore chose to focus on these concepts for a comparative review. The term 'Ecosystem Services' is also regularly associated with NBS, but is less solutions-oriented, signifying more abstract ideas on valuing nature (Pauleit et al., 2017), and is therefore not included in this review. In the second phase of data collection we retrieved literature on GI and EBA by running individual searches in Scopus on the concepts of EBA and GI. For GI, the query was TITLE-ABS-KEY ('green infrastructure' OR 'blue infrastructure' OR 'natural infrastructure'). For EBA, this was TITLE-ABS-KEY ('ecosystem-based adaptation'). We also added the search terms 'concept*' and 'definition*' to both queries (title, key words or abstract) in order to narrow down the number of search results to contributions focusing on conceptual foundations. In addition, we reviewed titles and abstracts in order to further narrow down the selection to 7 papers specific to EBA and 12 papers specific to GI, most of which were in-depth reviews in their own right.

To review the selected NBS literature, we focussed in particular on underlying assumptions and discussions regarding the two components of the NBS concept: 'nature-based' and 'solutions', as assumptions regarding these two labels are regularly displayed in existing definitions of NBS (Albert et al., 2019; Bridgewater, 2018; Nesshöver et al., 2017; Scott et al., 2016). We did so by addressing the following questions:

1 How is 'nature-based' conceptualised and operationalised? We examined how the use of nature is understood and how nature is translated into interventions.
2 What does 'solutions' entail in regard to urban planning? We examined the objectives associated with the concept, the associated governance and planning approaches (including key governing actors) and the role of socio-spatial embeddedness.

The literature was coded using the qualitative data analysis software NVivo (Bazely & Jackson, 2007; Welsch, 2000). This analysis resulted in an overview of the most prominent characteristics of the NBS approach, which were compared to those of EBA and GI.

4. Results

The main characteristics of NBS that emerged from the review are summarised in Table 1, which allows for easy comparison with characteristics associated to EBA and GI. The comparison between the concepts is further elaborated upon in Section 4.1 and 4.2.

4.1. Forms of nature

A key subject of debate is one of the defining features of NBS – their functioning on the basis of natural elements and systems – which raises the challenge of "where to draw the line as to what is considered 'nature' or 'natural'?" (Nesshöver et al., 2017, 1220). Various perspectives exist on what kinds of nature are included in NBS. Maes and Jacobs (2015, 121) refer to NBS as 'living solutions'. The European Commission (2015), often referred to in the academic literature on NBS, interprets 'nature-based' more broadly, although it does exclude interventions that represent artificially altered nature, such as genetically modified organisms. Both perceptions contrast with the typology provided by Pontee, Narayan, Beck, and Hosking (2016), which includes 'fully natural' solutions, i.e. naturally occurring phenomena, 'managed' natural solutions, such as planted, re-nourished or artificial natural features, 'hybrid solutions', which combine natural features and structural engineering, and 'environment-friendly structural engineering'. Eggermont et al. (2015) use a similar typology, ranging from the improved use of existing ecosystems to the construction of new ecosystems, the latter also including 'artificial ecosystems'.

Divergent understandings of nature are also apparent in the GI literature. Some claim that GI elements can be natural, semi-natural or

Table 1
NBS contrasted to EBA and GI.

		Nature-Based Solutions (NBS)	Ecosystem-Based Adaptation (EBA)	Green Infrastructure (GI)
'Nature-based'?	Forms of nature included	Mixed perceptions of what constitutes nature; artificial (e.g. biomimicry) or hybrid solutions (combining natural and engineered components) sometimes included	Dissimilar to NBS: nature entails ecosystems and biodiversity but not artificial forms of nature	Similar to NBS, yet emphasis on interconnectedness of green and/or blue spaces
	Functions of nature	Utilitarian conceptualization of nature; nature can provide multiple benefits to society	Similar to NBS	Similar to NBS
	Nature as intervention – examples	Wide-ranging perceptions of what interventions are considered NBS; variety in scope, scale and range of functions Main examples: green roofs and walls, sustainable urban drainage systems (SUDS)	Dissimilar to NBS: generally shared view of what are relevant examples; refers to the management, conservation and restoration of ecosystems Main examples: coastal defence through vegetation, wetland management, urban green spaces	Similar to NBS Main examples: green roofs, ecological corridors, gardens, parks or plans for such interventions
'Solutions'?	Objectives and expected benefits	Aimed at addressing social, economic and environmental issues simultaneously Explicitly solution-oriented	Similarly aimed at addressing multiple sustainability challenges Emphasises climate change adaptation as key outcome	Similarly aimed at addressing multiple sustainability challenges
	Governance approaches	Involves trade-offs between co-benefits; integrative and holistic approach promoted Characterised by involvement of a variety of stakeholders	Similar to NBS; advocates de-compartmentalisation within governmental organisation for more effective governance Similar to NBS; advocates participatory, community-based management approaches	Similar to NBS; advocates cross-disciplinary collaboration Originally a strategic, somewhat technocratic approach, emergent shift to a socially inclusive approach
	Socio-spatial embeddedness	Alignment with socio-ecological and institutional context is essential to effective functioning Urban context increasingly recognised as key context for NBS implementation	Similar to NBS; advocates adaptation to place-based features and relies on contributions by local communities Increasing attention for embedding in an urban context	Similar to NBS Roots in planning theory and practice; perceived as a well-suited approach to address the complexities of converging social, economic and environmental interests in cities

artificial (Tzoulas et al., 2007). Others identify a divide between GI that is visually and ecologically 'green' and infrastructures with more sustainable, environmentally friendly functions (e.g. renewable energy) (Wright, 2011). Mell (2012) proposes a 'new' type of approach that combines both visual and functional GI, while arguing for planners and practitioners to consider the entire green–grey continuum of interventions as long as the outcome of such infrastructures contributes to sustainability. Key to all GI approaches, however, is the emphasis on the interconnectedness of natural areas (Benedict & McMahon, 2002). Within the literature on EBA, ecosystems and biodiversity are central concepts, indicating that perceptions of nature in this literature emphasize ecosystems as a whole.

4.2. Functions of nature

A key feature of all three approaches is the multifunctionality of interventions. Nature-based interventions have the potential to address challenges in social, economic and ecologic domains simultaneously (Benedict & McMahon, 2002; Di Marino & Lapintie, 2017; Matthews, Lo, & Byrne, 2015; Mell, 2012; Sussams, Sheate, & Eales, 2015; Tzoulas et al., 2007). The multifunctionality of NBS, EBA and GI is related to their natural features, which sets them apart from more traditional 'grey' urban planning interventions. In some instances, ecosystem services is regarded to be a foundational concept of NBS, signalling how nature provides benefits to society (Eggermont et al., 2015; Pontee et al., 2016; Potschin et al., 2014). The ecosystem services concept was developed to integrate ecological principles into economic decision-making (Pauleit et al., 2017; Wamsler, 2015); Chong (2014) signals a "trend towards commoditisation" in relation to ecosystems and the services they deliver, where interdependencies between nature and society are interpreted from a rather utilitarian and anthropocentric perspective.

4.3. Nature as intervention

Similar interventions are referred to as either NBS, EBA or GI (e.g. urban gardens, waterways, or green roofs – see Appendix 1 for all examples in the reviewed literature). Moreover, several authors consider GI, and to a lesser extent also EBA, to be sub-categories of NBS (Derkzen, van Teeffelen, & Verburg, 2017; Fink, 2016; Giannakis, Bruggeman, Poulou, Zoumides, & Eliades, 2016; Haase, 2015; Marando, Salvatori, Fusaro, & Manes, 2016; Nesshöver et al., 2017; Scott et al., 2016). The NBS literature covers a wide array of interventions, varying in scope (from pervious pavements to urban forests), scale (from individual building greens to metropolitan regions and beyond) and the range of functions provided (from water retention to social cohesion) (Derkzen et al., 2017; Pontee et al., 2016; Raymond et al., 2017a,b). Likewise, the GI literature refers to a broad and partially overlapping spectrum of practices, ranging from physical interventions to planning and design approaches and general models for urban development (Wright, 2011). EBA practices have been more narrowly operationalised. They tend to cover the sustainable management, conservation and restoration of ecosystems, rather than individual natural urban infrastructure elements like green roofs or parks (Brink et al., 2016).

4.4. Objectives and expected benefits

NBS aim broadly at societal change, which, in addition to the label solutions, is indicated by terms such as 'sustainable development' or 'transition' used in defining NBS (Liquete, Udias, Conte, Grizzetti, & Masi, 2016; Maes & Jacobs, 2015). GI and EBA have similar objectives, although EBA objectives are generally more specific: the approach primarily addresses climate change effects (Brink et al., 2016; Milman & Jagannathan, 2017). For NBS, the label solutions signals a distinctive element of the concept vis-à-vis similar concepts, at least semantically, as it explicitly unites 'actions' with 'addressing problems'. Compared to GI and EBA, the objective of addressing complex societal challenges is more prominent in the NBS literature (Maes & Jacobs, 2015; Potschin et al., 2014; Nature editorial, 2017); NBS is considered to provide more focus and immediacy as a planning approach than GI (Davies & Lafortezza, 2019). In addition, Kabisch et al. (2016) note the concept to be more explicitly aimed at solving urban sustainability issues. However, all three approaches are to some extent solution-oriented and promote social, economic and environmental objectives simultaneously (Bennett, Cassin, & Carroll, 2016; Capotorti, Mollo, Zavattero, Anzellotti, & Celesti-Grapow, 2015; Connop et al., 2016; Fini, Frangi, Mori, Donzelli, & Ferrini, 2017; Fink, 2016; Liquete et al., 2016; Xing, Jones, & Donnison, 2017). The NBS literature promotes a lack of hierarchy between these objectives, each carrying the same level of importance (Frantzeskaki, 2019; Nesshöver et al., 2017). However, in practice such hierarchies do exist, with social and economic objectives sometimes being valued more than environmental ones (Brink et al., 2016; Chong, 2014; Garmendia et al., 2016; Raymond et al., 2017a; Raymond et al., 2017b; Engström, Howells, Mörtberg, & Destouni, 2018).

4.5. Governance approaches

NBS, as well as EBA and GI, aims to contribute to a variety of urban infrastructure functions (e.g. transportation, water, energy). Trade-offs are therefore likely to occur in the delivery of these multiple services (Eggermont et al., 2015; Haase et al., 2018). For instance, urban greening may result in 'green gentrification' as neighbourhood improvements bring about rising property values, social exclusion and displacement (Scott et al., 2016). The NBS literature therefore advocates a holistic governance approach that integrates the different policies, regulations and financial resources related to the different functions of NBS (Frantzeskaki, 2019; Xing et al., 2017). The literature on GI also considers this governance challenge: successful GI implementation requires integrated knowledge from different disciplines as well as cross-disciplinary cooperation (Andreucci, 2013; Hansen & Pauleit, 2014). If GI is driven from an isolated disciplinary or departmental entity, co-benefits are generally not integrated into the plans and impact on addressing multiple urban challenges is likely sub-optimal (Sussams et al., 2015). Similar concerns regarding fragmented governance are voiced in the literature on EBA (and climate adaptation governance more in general (Biermann et al., 2012; Chu, Anguelovski, & Roberts, 2017)). Engaging in EBA is often done in a compartmentalised way, in which responsibilities are divided over different governmental agencies and departments (e.g. related to climate change or disaster risk management), which counteracts effective governance (Wamsler, 2015).

Furthermore, the development of NBS affects a variety of stakeholders, such as community groups, local governments, businesses and investors or NGOs (Fink, 2016; Maes & Jacobs, 2015; Nesshöver et al., 2017; Xing et al., 2017). Frantzeskaki (2019) characterises NBS as a new 'green urban commons'. To achieve outcomes that benefit multiple stakeholders, the NBS literature argues for the need to include these groups in the planning, design and implementation process using a variety of participatory methods (Fink, 2016; Nesshöver et al., 2017; Raymond et al., 2017a,b; Davies & Lafortezza, 2019; Frantzeskaki, 2019). Similarly, EBA is characterised by participatory and flexible governance approaches across sectors and geographical scales with an emphasis on enabling communities to adapt to climate change (Chong, 2014; Dhar & Khirfan, 2016). 'Participation' takes different forms, ranging from top-down approaches in managing behaviour to bottom-up governance involving (self-organised) citizens, although bottom-up organisation receives the most attention in the EBA literature (Brink et al., 2016; Dhar & Khirfan, 2016; Milman & Jagannathan, 2017; Wamsler, 2015). Important stakeholders identified in the EBA literature are local communities, local governments and - especially - proactive

civil servants (Wamsler, 2015). Citizens, national governments or businesses are mentioned more sporadically, and so are international government bodies, such as the United Nations Framework Convention on Climate Change and the CBD (Brink et al., 2016). GI was originally more often considered a top-down planning exercise, but social inclusion is increasingly considered a key feature of GI planning as well (Andersson et al., 2018; Di Marino & Lapintie, 2017; Hansen & Pauleit, 2014). It is indicated that there is likely a range of potential stakeholders given GI's multifunctionality, such as businesses, planning authorities, conservationists, the general public and policymakers (Andreucci, 2013; Benedict & McMahon, 2002).

4.6. Socio-spatial embeddedness

NBS implementation is embedded in socio-ecological and institutional contexts (Nesshöver et al., 2017; Raymond et al., 2017b). Therefore, tailoring the natural and design features of NBS (e.g. the vegetation used) to characteristics of the social, economic and ecological environment is considered essential for NBS to function as solutions (Nesshöver et al., 2017; Pontee et al., 2016). The importance of such alignment is also emphasised in the EBA literature: the EBA approach promotes adaptation to place-based characteristics (Wamsler et al., 2014, 190) and relies largely on local communities (Dhar & Khirfan, 2016). Hansen and Pauleit (2014) note that the GI approach is well-suited to address the complex dynamics between the different socio-ecological systems concentrated in cities and could serve as a source of inspiration to NBS scholars interested in studying interactions between socio-ecological assemblages and built infrastructures. Urban areas are seen as important target locations for NBS implementation, because of the capacity of NBS to address the complex sustainability challenges encountered in cities and the potential role of cities in sustainable societal transformations (Droste, Schröter-schlaack, & Hansjürgens, 2017; Fink, 2016; Frantzeskaki, 2019; Kabisch et al., 2016; Scott et al., 2016). However, the review reveals that it is relatively understudied how NBS implementation can be practically achieved in an urban environment characterised by a concentration of coalescing infrastructures matched with a high diversity of stakeholders and interests.

5. Discussion

The review provided several insights into how the NBS concept is used and understood. Based on this review, and more specifically on the detailed conceptualisation of NBS vis-à-vis GI and EBA, we first propose what could be considered as the core principles or fundamental features of the NBS concept. Subsequently, we reflect on the implications of these principles for NBS planning and implementation.

5.1. Towards core principles of NBS

Four core principles were identified. A first principle of NBS is that *nature, as the concept's central foundation, may take many forms*. 'Nature-based' has been broadly interpreted in most papers on NBS, in terms of scope, scale and degree to which non-natural technology is included. For instance, examples included pervious pavements (Fini et al., 2017) as well as urban forests (Marando et al., 2016).

Second, NBS are characterized by *multifunctionality and a solution-orientation*; they address social, economic and environmental challenges simultaneously. Compared to related concepts, NBS is most explicitly oriented towards solving complex and multifaceted societal – and often urban – challenges in an innovative way (Davies & Lafortezza, 2019; Kabisch et al., 2016), which implies they are deliberate and targeted interventions. This is supported by how NBS are framed in policy and practice: as the intentional use of natural features to deal with sustainability challenges (European Commission, 2015; IUCN, 2016; WWAP, 2018).

Third, NBS require *implementation through holistic and integrative governance and planning approaches* given the need to integrate multiple values and disciplines. The NBS discourse seeks to show that it is rewarding to explore the potential for co-benefits in designing and implementing urban nature and, in doing so, to cross-sectoral boundaries and pursue collective decision-making (Davies & Lafortezza, 2019; Frantzeskaki, 2019).

As a fourth principle we identified the importance of *adaptation to place-based conditions*. NBS are place-based in regard to both their dependence, as well as their effects, on the socio-spatial environment. Therefore they are, similar to GI and EBA, not one-size-fits-all solutions; each NBS interacts with its environment in a different way, and can only qualify as 'solution' provided they address urban challenges with sensitivity to socio-spatial context (Haasse, 2017). It would be incorrect to think of NBS as universal interventions that can be copied from one place to another; rather, the concept represents many different interventions in any given context to many different actors. A mismatch with the socio-spatial context implies that the envisaged NBS no longer qualifies as a 'solution'.

5.2. Implications for implementing NBS

The assertion that NBS functions as an umbrella concept for different sustainability interventions that employ nature (Nesshöver et al., 2017; Pauleit et al., 2017) is supported by indications that the NBS concept encompasses a wider variety of interventions and interpretations of 'nature-based' than GI and EBA. At the very least, the existing overlap suggests that NBS builds upon similar visions of greening as GI and EBA. A key difference is that where GI emphasizes connecting natural areas and EBA underlines the functioning of nature as an ecosystem, the NBS approach more readily includes "detached" measures, such as a single green roof. Scale and connectedness matter for the extent to which natural elements can deliver social, economic and ecological value (e.g. in terms of contributing to biodiversity (Savard, Clergeau, & Mennechez, 2000)). However, the inclusion of relatively isolated interventions might also make NBS a more accessible measure, for example for actors that are less used to working with nature (e.g. companies choosing to implement a green roof on their office building) or for small or bottom-up citizen organizations. Additionally, it could improve chances for creating nature in places where fragmented land ownership makes connecting green space more difficult to achieve, such as in cities. Further research could investigate these hypotheses.

In being understood as an umbrella concept, the use of NBS leans towards that of a boundary concept (cf. Hoogstra-Klein, Brukas, & Wallin, 2017; Runhaar, 2017): it offers interpretive flexibility with scope for reflection, yet provides a solid enough foundation for different actors previously lacking a common language to work together (Opdam et al., 2015; Star, 2010). Reflecting on the implications of the multifunctional nature of NBS, we consider such a role to be valuable for both researchers and practitioners: it means that the NBS concept could indeed be employed to promote the necessary collaboration between disciplines (e.g. urban ecology, health and planning), sectors (e.g. water, food and mobility) and between practice and academia. Using the NBS concept also offers the opportunity to unite knowledge and experience from previous approaches to urban greening that have not yet been integrated (Albert, Spangenberg, & Schröter, 2017; Pauleit et al., 2017), which could contribute to innovative ways of visioning sustainable urban development.

The multifunctionality offered by the NBS concept may prevent a critical approach to establishing the hierarchy of functions: which objective is prioritized, and to what or whose problem is any particular NBS a solution? Practitioners and policymakers could enhance the implementation of NBS by more explicitly considering hierarchies between benefits and co-benefits as well as questions of social inclusion. Similar concerns about the trade-offs between co-benefits that multifunctional interventions bring have been raised in GI literature (Hansen

& Pauleit, 2014; Madureira & Andresen, 2014; Sussams et al., 2015). The GI literature advocates the strategic planning of green spaces as part of a broader infrastructure, which means that natural infrastructures are put on an equal footing with 'grey' infrastructures, and that economic, social and environmental benefits are weighed up early on in the design process (Benedict & McMahon, 2002; Matthews et al., 2015). Future research could inquire into the political processes leading to the implementation of multifunctional urban sustainability solutions, for instance by engaging with urban political ecology literature. This literature pays attention to the social and political processes through which socio-ecological urban conditions are constructed and has traditionally engaged with such questions (e.g., Swyngedouw & Heynen, 2003; Heynen, Kaika, & Swyngedouw, 2006). For instance, it has reflected on how problem definitions can lead to particular solutions (Lawhon & Murphy, 2012).

Furthermore, fragmented governance – with interests and responsibilities divided across governmental domains and disciplines – can limit the multifunctional potential of NBS. We envisage that, similar to EBA and GI, the multifunctionality aspect of NBS will challenge urban planners and developers to look beyond their own tasks and responsibilities. Further research could examine the extent to which the objective of providing multiple urban services may inspire novel governance and planning models. Environmental governance literature provides potential solutions to dealing with trade-offs between NBS benefits, by reflecting on more collaborative and integrative modes of governing urban nature (Driessen, Dieperink, Laerhoven, Runhaar, & Vermeulen, 2012). For instance, Brink et al. (2018) discuss 'research municipalities', a model that promotes transdisciplinary governance, or Buijs et al. (2016) introduce the concept of 'mosaic governance' which reflects a strongly developed nexus between active citizens and municipalities. The EBA literature also offers value with its focus on participatory approaches in decision-making and implementation and on the importance of connecting to local knowledge (Dhar & Khirfan, 2016; Wamsler et al., 2014).

Taken together, the core principles outlined above imply that urban greening through NBS likely benefits from spatial planning approaches that accommodate flexibility and the integration of multiple land uses, and that are solution-oriented (Xing et al., 2017). A performance-based land use planning approach, as opposed to a more traditional prescriptive zoning approach, provides such a perspective (Baker, Sipe, & Gleeson, 2006; Frew, Baker, & Donehue, 2016). It is better suited to accommodate land use multifunctionality, which is increasingly required in the complex socio-ecological urban systems – where diverse social networks and actions are intertwined with natural ecosystems (Bettencourt, 2013; Moroni & Cozzolino, 2019; Pelorosso, Gobattoni, & Leone, 2017) – that NBS cater to. Although NBS and related concepts have been discussed relatively little within performance-based planning, this planning approach fits NBS characteristics and the necessary requirements for their implementation and management well. A primary objective of the approach is to tailor land use to site characteristics, and allow for the integration of functions in land use (Baker et al., 2006; Frew et al., 2016). In doing so, performance-based planning centralizes the multifunctionality and adaptation to local socio-ecological conditions that are essential to the NBS approach. Its orientation towards outcomes and effects (Baker et al., 2006) may benefit NBS implementation by promoting the consideration of ecosystem services that a given urban area could provide. Lastly, in aiming for urban sustainability, performance-based planning promotes a less 'siloed' approach to organising urban planning and development (Steele, 2011).

6. Conclusion

Based on a review of NBS literature, and a comparison with the related GI and EBA literatures, this review set out to identify key characteristics of the emerging NBS concept. We focused in particular on underlying assumptions regarding what is 'nature-based' and implications of its explicit solution-orientation for urban planning practices.

We found several similarities between NBS, EBA and GI. Each of the concepts is aimed at developing nature-based interventions with high multifunctionality, following from a somewhat anthropocentric perspective on nature. As all three approaches aim at delivering social, environmental and economic benefits simultaneously, there is a risk of fragmented governance and implementation processes due to the various interests involved, which is why holistic and participatory governance and planning approaches are required. The three concepts vary regarding perspectives on what qualifies as 'nature', and related to that, around what qualifies as a nature-based intervention. As NBS cover the broadest range including EBA and GI types of interventions, it acts as an umbrella for all kinds of nature-based interventions. The NBS concept further stands out by its explicit solution-orientation, which means it can provide a common language for actors with different disciplinary backgrounds aiming to address urban sustainability challenges.

Not all of the core principles of NBS differ fundamentally from those of the established concepts of GI and EBA. NBS may therefore be partially characterised as 'old wine in new bottles'. Yet as an umbrella concept, it offers the potential to connect currently segregated bodies of knowledge and expertise generated as part of previous and current approaches to urban green planning. In addition, its specific focus on real-world solutions to intertwined social, economic and environmental sustainability challenges makes it an approach that can be particularly effective in drawing attention to the potential of nature in devising pathways to urban sustainability transformations. NBS implementation therefore likely benefits from using more performance-based urban planning approaches that accommodate flexibility and the integration of multiple land uses, and are oriented towards providing solutions for urban sustainability.

Declarations of interest

None.

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Appendix 1 Overview of interventions derived from the reviewed literatures on NBS, EBA and GI

	Nature-based Solutions (NBS)	Ecosystem-based adaptation (EBA)	Green Infrastructure (GI)
Examples of NBS	urban and peri-urban forests (Fink, 2016; Davies, Doick, Hudson, & Schreckenberg, 2017; Tomao et al., 2017; Yao, Zhao, & Escobedo, 2017); green roofs and walls (Eggermont et al., 2015; Haase, 2015; Scott et al., 2016; Xing et al., 2017; Frantzeskaki, 2019); parks and trees (Fink, 2016; Giannakis et al., 2016);	green spaces; trees and shrubs; wetlands; parks and gardens; coastal vegetation maintenance or	green roofs; ecological corridors; waterways; gardens; parks; and

greenways and corridors (Haase, 2015; Giannakis et al., 2016);
green-bordered ponds, park-like water retention areas or bioswales (Haase, 2015; Scott et al., 2016; Xing et al., 2017);
pervious pavements (Fink, 2016; Fini et al., 2017) ;
urban gardens (including rooftop gardens) (Haase, 2015; Lafortezza & Sanesi, 2019) and rain gardens (Scott et al., 2016); and
urban agriculture (Russo et al., 2017)
waterways, use or restoration of vegetation to improve water system (Pontee et al., 2016; Lafortezza & Sanesi, 2019)
restoration;
wetland floodplains management;
conservation and restoration of vegetation and forests;
agro-forestry systems (Chong, 2014; Dhar & Khirfan, 2016);
re-naturalising river systems;
maintaining or enhancing urban green;
promoting the use of vegetation adapted to local conditions/climate; and
waterways (Wamsler & Pauleit, 2016)
measures for implementing or enhancing such areas (Tzoulas et al., 2007; Andreucci, 2013)
Note: these spaces are components that, when interconnected, form GI

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