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Perspective Essay

Addressing societal challenges through nature-based solutions: How can landscape planning and governance research contribute?

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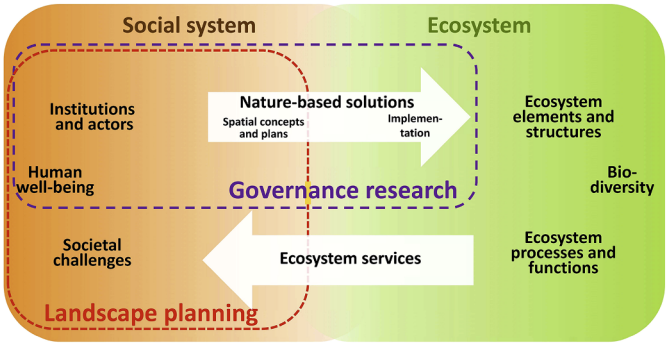
GRAPHICAL ABSTRACT



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ABSTRACT

Nature-based solutions (NBS) in river landscapes, such as restoring floodplains, can not only decrease flood risks for downstream communities but also provide co-benefits in terms of habitat creation for numerous species and enhanced delivery of diverse ecosystem services. This paper aims to explore how landscape planning and governance research can contribute to the identification, design and implementation of NBS, using the example of water-related challenges in the landscape of the Lahn river in Germany. The objectives are (i) to introduce the NBS concept and to provide a concise definition for application in planning research, (ii) to explore how landscape planning and governance research might support a targeted use and implementation of NBS, and (iii) to propose an agenda for further research and practical experimentation. Our methods include a focused literature review and conceptual framework development. We define NBS as actions that alleviate a well-defined societal challenge (challenge-orientation), employ ecosystem processes of spatial, blue and green infrastructure networks (ecosystem processes utilization), and are embedded within viable governance or business models for implementation (practical viability). Our conceptual framework illustrates the functions of NBS in social-ecological landscape systems, and highlights the complementary contributions of landscape planning and governance research in developing and implementing NBS. Finally, a research and experimentation agenda is proposed,

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focusing on knowledge gaps in the effectiveness of NBS, useful approaches for informed co-design of NBS, and options for implementation. Insights from this paper can guide further studies and support testing of the NBS concept in practice.

1. Introduction

Nature-based solutions only relatively recently emerged in environmental policy and science communities as a term to describe efforts that utilize ecosystem processes rather than technical engineering to address societal challenges (Cohen-Shacham, Walters, Janzen, & Maginnis, 2016). The World Bank (2008), the International Union for the Conservation of Nature (IUCN), and several other organizations began to refer to NBS for describing ecosystem-based approaches to climate change adaptation (Dudley et al, 2010). More recently, the idea of NBS was adopted in major research and innovation approaches (Balian, Eggermont, & Le Roux, 2014; European Commission, 2015; Balian et al. 2015).

River landscapes arguably provide a particularly useful setting for making use of NBS. Over the last centuries, river landscapes have been substantially altered through actions such as river straightening in order to enhance navigation, embankments for flood protection, the conversion of floodplains into areas for settlement, and the intensification of agriculture to increase productivity (Gilvear, Spray, & Casas-Mulet, 2013; Pahl-Wostl et al., 2007; Pahl-Wostl, 2007). These landscape changes have given rise to several unintended, mostly water-based challenges for society, for example by exacerbating floods, creating shortages of water in times of drought, and diminishing water quality due to pollutants such as nitrogen or phosphorous (Matthies, Berlekamp, Lautenbach, Graf, & Reimer, 2006). In addition, the changes have often decreased the ecological condition of rivers and river landscapes, altered the types and amount of habitats present, and reduced both number and diversity and amount of ecosystem services provided (Seppelt, Dormann, Eppink, Lautenbach, & Schmidt, 2011). Many of the ecosystem services and much of the biodiversity lost can probably be brought back through restoration of rivers and river landscapes (Gilvear et al., 2013; Opperman et al., 2009; Schindler et al., 2016).

Landscape planning and governance research could potentially provide many insights and experiences in developing and implementing NBS river landscapes to alleviate societal challenges. Acknowledging the various interpretations of landscape planning in different contexts (cf. Selman, 2010), we refer to landscape planning here broadly as “a strong forward-looking action to design, enhance or restore landscapes” (Council of Europe, 2000) that serves at the interface between science and practice (Nassauer & Opdam, 2008). Governance research can be understood as the study of characteristics, effects, and dynamic interactions between institutions and actors (Vatn, 2010; Williamson, 2000). Governance research analyses existing actors and institutions and their influence on a decision making and implementation of policies in a given institutional setting (cf. Beunen & Opdam, 2011, see section 3 for more details). While landscape design, planning and good governance are frequently referred to as essential for the implementation of NBS (cf. e.g. Nesshöver et al., 2017; Raymond et al., 2017), little knowledge so far exists of how the NBS concept could be scientifically defined for application in planning, and which specific roles landscape planning and governance research could play in implementing NBS in practice.

The aim of this paper is to explore how landscape planning and governance research can contribute to the identification, design and implementation of NBS at landscape scale, using the example of water-related challenges in the Lahn river landscape in Germany. The objectives are (i) to introduce the NBS concept and to provide a concise definition for application of the concept in planning research, (ii) to explore how landscape planning and governance research might support a targeted use and implementation of NBS, and (iii) to propose an agenda for further research and practical experimentation.

Three methods have been employed. First, the proposed scientific definition of NBS was developed based on suggestions for operationalization by Nesshöver et al. (2017) and Albert, Spangenberg, and Schröter (2017). Second, and in order to explore potential contributions from landscape planning and governance research to NBS implementation, a conceptual framework was developed (according to the method proposed by Tomich et al., 2010) and used as the basis for elaboration. Finally, the complementary contributions of landscape planning for designing NBS, and governance instruments for implementation were identified in a meta-synthesis (Newig & Fritsch, 2009) of relevant publications.

2. Characterizing nature-based solutions

In response to the high interest from policy, the NBS concept is increasingly in focus of scientific scholarship. Some first peer-reviewed publications on the NBS concept have emerged, including a first typology of NBS (Eggermont et al., 2015), an exploration of its potential for supporting sustainable development in Europe (Maes & Jacobs, 2015) and the US (McPhearson et al., 2016), a review of implications for application in urban areas (Kabisch et al., 2016 for Europe), comparative studies for the US (Falxa-Raymond, Palmer, McPhearson, & Griffin, 2014; Nowak, Hirabayashi, Bodine, & Greenfield, 2014) and for urban regeneration in a natural disaster vulnerability context in China (Xiang, Wang, & Deng, 2017). Conceptual advances have been made regarding a synthesis of interdisciplinary perspectives on NBS (Nesshöver et al., 2017), relationships between NBS, ecosystem-based adaptation and ecosystem services (Pauleit, Zölch, Hansen, Randrup, & Konijnendijk van den Bosch, 2017), and NBS contributions to sustainability transitions (Frantzeskaki, Borgström, Gorissen, Egermann, & Ehnert 2017). Recently, Raymond et al. (2017) proposed an impact evaluation framework around NBS for promoting climate resilience in urban areas. The concept now seems to have found high attraction in science, with increasing numbers of papers on NBS published per year (e.g. 4, 21 and 62 papers in 2015, 2016 and 2017, respectively according to the Web of Science).

Among the various definitions proposed for NBS, the two most prominent ones are from IUCN and the European Commission. The IUCN (Cohen-Shacham et al., 2016) defined NBS as “actions to protect, sustainably manage and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits”. The European Commission (EC) has proposed a slightly different definition of NBS as “actions which are inspired by, supported by or copied from nature. They have tremendous potential to be energy and resource-efficient. … Many nature-based solutions result in co-benefits for health, the economy, society and the environment, and thus they can represent more efficient and cost-effective solutions than more traditional approaches” (European Commission, 2015). Both definitions share the notions that NBS address societal challenges by using ecosystem processes and by providing several co-benefits for nature and people. However, the IUCN definition focuses more on the protection, sustainable management and restoration of ecosystems, while the European commission employs a broader notion including actions that are only ‘inspired’ or ‘supported’ by nature (cf. Cohen-Shacham et al.,

2016). In addition, the European Commission seems to connect more ambitious social and economic innovation goals with NBS such as their capacity to "contribute to green growth, 'future-proofing' society, fostering citizen well-being, providing business opportunities and positioning Europe as a leader in world markets" (European Commission, 2015).

Both IUCN and the European Commission have suggested priority areas that could be addressed by NBS. IUCN interprets NBS development in the five areas of water security, food security, human health, disaster risk reduction and climate change as particularly topical (Cohen-Shacham et al., 2016). The European Commission identifies seven areas for research and innovation on NBS that are mostly in line with the IUCN priorities, including NBS for regeneration and well-being in urban areas, carbon sequestration, coastal resilience, watershed management and ecosystem restoration. The European Commission also adds two topics that go beyond the scope of the IUCN's interpretation, namely NBS to enhance the insurance value of ecosystems and to foster sustainable use of matter and energy (European Commission, 2015).

The idea to address the societal challenges within these priority areas by harnessing ecosystem processes is not new but already rooted in a great number of similar, ecosystem-based approaches (see, for example, the early example by McHarg, 1969). Several commentators have therefore proposed to understand NBS as an umbrella concept for biodiversity and ecosystem stewardship (Cohen-Shacham et al., 2016; Nesshöver et al., 2017) that can synthesize and build upon such prior experiences. Existing ecosystem-based approaches can be grouped into several categories (Cohen-Shacham et al., 2016). Ecosystem protection and restoration approaches involve fields such as protected areas management, ecological restoration, 'green' engineering and forest landscape restoration (e.g. Palmer, Filoso, & Fanelli, 2014; Urgenson et al., 2017). Issue-specific ecosystem-related approaches include ecosystem-based adaptation, ecosystem-based mitigation, climate adaptation services, and ecosystem-based disaster risk reduction (Renaud, Nehren, Sudmeier-Rieux, & Estrella, 2016; Scarano, 2017). Green infrastructure and natural infrastructure approaches have been proposed by both the European Commission (European Commission, 2013) and the US Army Corps of Engineers, albeit under the term natural and nature-based measures (Bridges, Henn, Komlos, Scerno, Wamsley, & White, 2013).

NBS approaches can be broadly classified into three types along a gradient of the level and intensity of engineering applied (Eggermont et al., 2015): Type 1 NBS approaches involve no or minimal intervention in ecosystems to maintain or improve the delivery of ecosystem services, type 2 measures aim at establishing sustainable and multifunctional landscapes and ecosystems, and type 3 NBS actions manage ecosystems in very intensive ways or create new ecosystems.

Finally, implementing NBS can draw on experiences from comprehensive planning and management approaches such as environmental planning, integrated coastal zone management, and ecosystem-based management (Bendor, Spurlock, Woodruff, & Olander, 2017; Shipman & Stojanovic, 2007; von Haaren & Albert, 2011). In addition to these approaches for defining NBS, we found two properties of the term that should be considered when specifying a definition applicable in landscape planning and governance research. Firstly, the term 'nature-based' entails a descriptive part, suggesting that natural (or self-regulating) ecosystem processes are essential for the definition. Second, the term 'solution' implies that a particular challenge or problem should be solved. The reference to solutions clarifies that ecosystem processes are evaluated here regarding their capacity to contribute to problem-solving. Ecosystem processes are not per se better than technical measures. NBS often require more space and time, and sometimes more funding than comparable technical alternatives to problem-solving, i.e. technical solutions could be more cost- or space-efficient (cf. Galler, von Haaren, & Albert, 2015). The contribution of NBS to alleviating challenges is less easy to prove empirically (Kabisch, Korn, Stadler, & Bonn, 2017), funding or insurance schemes for NBS will often be more complex than with technical alternatives, and implementation of NBS often requires long-term coordination and cooperation among diverse land owners and users (Davis & Naumann, 2017). For example, river dikes minimize flood risks of downstream communities with much less space than revitalized floodplains, but without the co-benefits that the active floodplains would deliver. In some cases, choosing a technical solution and using the saved space for targeted measures to improve certain ecosystem services could result in a greater ecosystem services delivery and societal benefit than if a supposedly multi-functional NBS had been chosen. Against this background, NBS are not always the 'best' solution, and exploring the place-specific implications of each alternative has to be addressed in landscape planning. Thus, in comparison with the numerous preceding approaches, the NBS concept implies three important innovations: i) its strongly normative focus on the development of applicable solutions, ii) its embodied systemic perspective, and iii) its inherently transdisciplinary approach of co-creating, co-developing and co-implementing actions to alleviate challenges and exploit co-benefits (cf. Kabisch et al., 2017, for a more critical perspective, see Nesshöver et al., 2017). The provision of these co-benefits is a key advantage of NBS over technical alternatives which usually simply target the challenge without providing additional benefits. Another advantage of NBS may embody, compared to pure technical solutions, the provision of early warning signals (cf. Jongman, 2018).

A key challenge for applying NBS as an umbrella concept is its vagueness concerning which interventions in landscapes would qualify as NBS, and which actions would not. Especially for use in a scientific and planning context, providing a more clear-cut definition of NBS is needed in order to provide some structure for and comparability across studies (Albert et al., 2017; Nesshöver et al., 2017). For application in landscape planning and governance research, we define NBS 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. In short, NBS must fulfill the criteria of challenge-orientation, ecosystem process utilization and practical viability (see Fig. 1 for illustration). Key societal challenges for which NBS could provide solutions include enhancing human health and well-being, food security, climate mitigation and adaptation, sustainable urban development, disaster risk management, and conserving and enhancing biodiversity (European Commission, 2015; Kabisch et al., 2016; Raymond et al., 2017). The term does not imply that NBS are automatically superior to technical solutions. It is the task of landscape planning to include NBS as one type of solution which could deliver many co-benefits, but to jointly identify and create the best solution for the specific planning context, considering also the status quo, different NBS, and technical alternatives.

Especially in river landscapes, NBS may have many advantages over technical solutions. Societal challenges in river landscapes are often water-related, including flooding, droughts, and water quality deficits (e.g. Pahl-Wostl, 2007). In each case in which NBS is used, the specific problem to be addressed and the affected actors need to be specified. Ecosystem processes to be harnessed by NBS can be understood as any change or reaction occurring within ecosystems, including physical, chemical or biological changes (Maes et al., 2013). Examples of ecosystem processes in river landscapes include water and nutrient cycling, decomposition and production. Our definition argues that such ecosystem processes can be used by NBS through safeguarding, restoring or enhancing green and blue infrastructures. Green and blue infrastructure is thereby understood as a strategically planned and managed, spatially interconnected network of multi-functional, land-based (green) or water-based (blue) landscape features that deliver a variety of

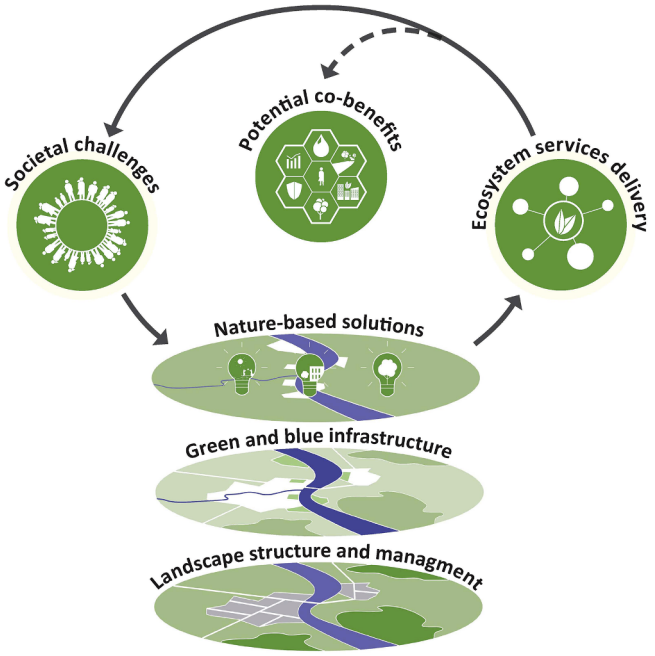

Fig. 1. Conceptual understanding of NBS and their effects. We define NBS as actions that (i) alleviate a well-defined societal challenge, (ii) utilize ecosystem processes of spatial, blue and green infrastructure networks, and (iii) are embedded within viable governance or business models for implementation. Key societal challenges for which NBS could provide solutions include enhancing human health and well-being, disaster risk management, and conserving and enhancing biodiversity. NBS themselves consist of predominantly natural features but can also include technical components such as pumps and valves for intentional floodplain water level management. NBS utilize ecosystem processes of green and blue infrastructure in order to safeguard or enhance the delivery of ecosystem services. The safeguarding and enhanced provision of preferred ecosystem services can in turn contribute to the alleviation of societal challenges, but also simultaneously provide economic, human security, social/cultural, and ecological co-benefits.

ecosystem services (e.g. Albert & von Haaren, 2014; European Commission, 2013; Haase, 2015). At this point, the different spatial scales on which NBS can take place have to be considered. NBS can be more clearly defined at the level of particular actions, which are based predominantly on the mentioned ecosystem processes. On the scale of green and blue infrastructures, NBS will be more intertwined with technical solutions (cf. Eggermont et al., 2015; McPhearson et al., 2016).

Finally, our definition incorporates the notion that proposed actions should be realizable and thus necessarily require viable governance or business models for implementation. As long as no such implementation concepts can be offered, suitable actions remain propositions, but cannot qualify as a solution. This is due to the need of cooperation and knowledge integration of actors from different fields or sectors, the institutional context within which these actors operate and the financial options that are available. An example for viable governance and business models for realizing NBS is the cooperation of state and market actors in the Florida Ranchlands Environmental Services Project where ranchers formulate bids in an output-based agri-environmental scheme that aims to increase rain water retention (Matzdorf et al., 2014; see also Fig. 2).

Our definition of NBS is thus in line with prior conceptions in its problem focus and the reliance on ecosystem processes. However, our definition does not require all NBS to provide those co-benefits. We argue that viable implementation models are needed and we state that co-benefits clearly can be provided and often will be greater than with technical alternatives. We acknowledge that many NBS will indeed provide co-benefits, but argue that it is not helpful in a scientific context to simply presume that all NBS will have these multiple positive outcomes. Instead, we see it as the task for planning and science to critically assess, for each proposed intervention, to what degree it can alleviate the problem at hand and what kind of co-benefits and trade-offs the intervention might yield. The analysis of co-benefits and trade-offs can enhance the transparency concerning the respective advantages and disadvantages of proposed actions, and enables more informed decision-making processes about sustainable landscape development.

To illustrate the functionality of NBS, we have selected three types of NBS representative of the numerous types of interventions in river landscapes that can qualify as NBS according to our criteria of challenge-orientation, ecosystem processes utilization and practical viability. The three examples we chose are i) revitalizing floodplains, ii) protecting and establishing wetlands, and iii) better adapting land-uses to site conditions within the watershed. An overview of the respective challenges and examples for associated NBS actions, ecosystem processes used, practical viability models and potential co-benefits is provided in Fig. 2.

3. Role of landscape planning and governance research in implementing nature-based solutions

By building upon recent propositions by Maes et al. (2016) and Díaz et al. (2015), our conceptual framework positions landscape planning and governance research within a systemic understanding of NBS and other interventions within the coupled social and ecological landscape systems (Fig. 3). The purpose of our conceptual framework is to clarify our understanding of the potential roles of landscape planning and governance in efforts for harnessing NBS with the aim of addressing societal challenges. As we acknowledge that landscapes are the result of the "action and integration of natural and/or human factors" (Council of Europe, 2000), we illustrate the social and ecological systems that landscapes are comprised of as closely merged and interlinked, especially in cultural landscapes that have evolved through the interaction of natural and human processes.

In its most simple version, the conceptual framework illustrates how human interventions, among them NBS, alter ecosystems and, in effect, the delivery of ecosystem services from which social systems benefit. We argue that NBS can help alleviating societal challenges by protecting, sustainably managing, restoring or creating ecosystems in ways that sustain and enhance the provision of those ecosystem services which minimize the challenges in focus. This particular perspective on solving societal challenges can serve as the added value of the NBS approach which is strongly solution-oriented and less analytic such as simple trade-off analyses of ecosystem services impacts. At the same time, NBS often result in an enhanced provision of several ecosystem services with additional positive impacts for human well-being (co-benefits).

Social systems, on the left side of the framework, are characterized by the pertinent societal challenges, the state of human well-being, and the institutions and actors. In order to address societal challenges such as flood risks, societal actors devise direct or indirect interventions that alter ecosystems. For example, decision-makers may opt to upscale technical flood defense or to provide more room to a river to enhance its water retention capacities. The impact of these interventions can be both positive or negative for and between ecosystems and human well-being (meaning different types of trade-offs; Haase, Schwarz, Strohbach, & Krol, 2012). Direct interventions are the immediate causes of changes in ecosystems such as altering land uses within the floodplain or changing the design level of the flood levees within the floodplain to allow more hydraulic dynamics. Examples of indirect drivers include agricultural policy changes such as new rules for agri-

Fig. 2. Characteristics of three exemplary NBS types in river landscapes. Figure credits: Löwenzahn, Piu_700, Erich Westendarp/pixelio.de.

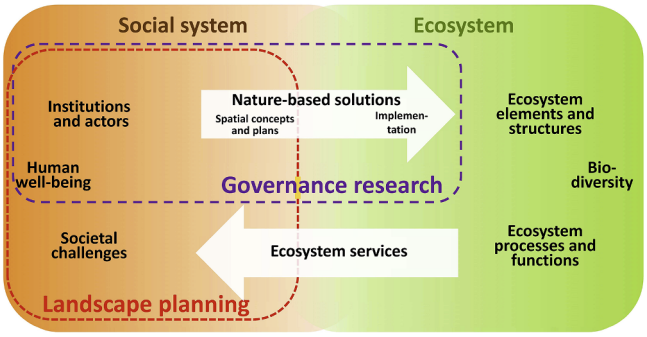

Fig. 3. Conceptual framework of landscape planning and governance research for nature-based solutions. Nature-based solutions are one of several categories of interventions that landscape planning can propose. Nature-based solutions differ from other interventions in that they fulfill specific criteria as elaborated in the manuscript. Note that the study area can be of different spatial size.

environmental measures which affect the direct interventions of cropping patterns and land use intensity on the ground (cf. Díaz et al., 2015). Those direct and indirect human interventions that fulfill the three characterizing criteria outlined in Section 2 above can be regarded as NBS.

Ecosystems, illustrated in the right side of the framework, can be safeguarded, sustainably used or restored through NBS in order to ensure or enhance the provision of biodiversity and ecosystem services. The preservation of biodiversity is of importance for several ecosystem functions and services (Cardinale et al., 2012). The degree to which NBS can enhance biodiversity and ecosystem services provision depends on the characteristics of the specific ecosystem, its elements, structures, processes and functions (cf. de Groot, Alkemade, Braat, Hein, & Willemen, 2010). Ecosystem services represent the key process through which NBS can both alleviate societal challenges (for example if water retention limits flood risks) and provide the co-benefits (such as recreational benefits) of NBS (cf. Section 2). Ecosystem services are understood here as the direct and indirect contributions of ecosystems to human well-being (TEEB, 2010), which can be classified into provisioning, habitat or supporting, regulating and maintaining, and cultural ecosystem services (cf. e.g. Haines-Young & Potschin, 2013; TEEB, 2010). In river landscapes, provisioning services include raw materials, renewable energy, water for drinking and other purposes, as well as food from terrestrial and aquatic sources. Regulating services in river landscapes concern a wide variety of services such as water purification, air quality regulation, flood protection, greenhouse gas sequestration, and local climate regulation. Cultural ecosystem services of river landscapes encompass, among others, symbolic services, knowledge, and experiential aspects such as recreation (Böck, Muhar, Muhar, & Polt, 2015; Gilvear et al., 2013; Schindler et al., 2014; Yeakley et al., 2016).

Having characterized our understanding of the processes through which NBS can alleviate societal challenges, we can now explore the functions of landscape planning and governance. Given the definition of landscape planning as action to conserve, restore, enhance or create landscapes (cf. introduction and Council of Europe, 2000), landscape planning has a potential to suggest land use options to achieve environmental objectives, to explore the respective impacts, and to provide recommendations for implementation in practice (von Haaren & Albert, 2011). One aim of landscape planning is to craft comprehensive and spatial strategies for developing multifunctional landscapes that minimize societal challenges and provide diverse ecosystem services to different groups of people (Galler et al., 2015; McPhearson et al., 2016; Selman, 2010). As such, many of the strategies and actions frequently proposed by landscape planning can be interpreted as NBS, for example the restoration of creeks and rivers, the integration of conservation targets in agricultural management, and the conservation and restoration of peatlands. Landscape planning could help in identifying, designing, evaluating and implementing NBS as an integrated approach to water and spatial planning within river basins (Wiering & Immink,

2006). Within the conceptual framework, we propose that landscape planning, understood in a broad sense, can consider the entire spectrum of the social system, with one aim being to support navigating the coupled social-ecological landscape systems (Angelstam, Elbakidze, Axelsson, Dixelius, & Törnblom, 2013; Sattler et al., 2016) towards more sustainable pathways (Potschin & Haines-Young, 2013; Selman, 2010; Wu, 2013). Along this broad understanding, landscape planning can contribute to enhancing human well-being and achieving the objectives of diverse actors. Furthermore, landscape planning can support the consideration of societal challenges, including the protection of biodiversity or the minimization of social exclusion and poverty, even though substantial barriers often still exist for successful implementation (cf. Sandström, Angelstam, & Khakee, 2006). If appropriately implemented, landscape planning acknowledges the institutional and actor context of the place, including a transdisciplinary approach that systematically involves relevant actors, and proposes spatial concepts and plans concerning interventions for the safeguarding and sustainable use of biodiversity and ecosystem services within landscapes (cf. Potschin & Haines-Young, 2013).

We propose that landscape planning for NBS adopts an ecosystem-based perspective on river landscapes in order to develop planning strategies that address the effects of and interactions between changes in the river, its floodplain, and the surrounding landscapes. In this way, the concept of NBS can provide a new impulse for landscape planning to facilitate the implementation of a 'true' ecosystem approach in river basin management, meaning an approach acknowledging ecosystem structures and processes in all spatial-temporal dimensions, thus further advancing current paradigms of integrated water management planning and river basin management. The specific contributions of landscape planning to the realization of NBS could lie in the provision of relevant spatial information for decision support concerning the location and causes of societal challenges, potential solution strategies, and their respective impacts (see Table 1). Landscape planning has a wealth of experience in using participatory and transdisciplinary approaches to planning that enable the co-identification, co-design, and co-exploration of decision options in order to develop actionable knowledge for implementation (Albert, Zimmermann, Knieling, and von Haaren, 2012; Luz, 2000; Opdam et al., 2013; Reyers et al., 2010).

Governance research complements landscape planning with considerations of relevant actors, institutions, and their dynamic interactions that influence the realization of strategies for sustainable landscape development. Institutions describe key policy processes and actors' relationships (the 'rules of the game'), while actors (the 'play of the game') determine how these institutions are employed (Vatn, 2010; Williamson, 2000). In river landscapes, actors include the political decision makers concerned with river and landscape development at various levels, economic stakeholders such as tourism businesses (e.g nature-inclusive farming, insurance companies, water transport companies), and civil society representatives such as fishing clubs and nature conservation organizations. Formal institutions include water management as well as settlement and infrastructure development plans. Informal institutions comprise existing values, norms, traditions or ideologies. Some institutions include both formal and informal aspects, for example the WFD's formal requirement to implement stakeholder participation without specifying how it should be conceptualized and implemented. The contributions of governance research to NBS identification and development will lie primarily in providing an enhanced understanding of the current system of relevant institutions and actors, in highlighting best practice-examples of how NBS can be implemented, and in facilitating the co-creation and co-implementation of funding, business, and governance models for implementing NBS in practice.

Landscape planning and governance research can thus provide useful and complementary contribution to the co-identification, co-design, and co-implementation of strategies that harness NBS to address societal challenges. By using the NBS concept, an integrative and systemic approach to planning and governance research can be assumed that might provide new opportunities for enhancing the understanding, interest, political support and uptake of strategies for more sustainable landscape development. Broad evidence and diverse experience is already available in the fields of landscape planning and governance research that efforts for planning and implementing NBS can draw from and build upon (cf. Termorshuizen & Opdam, 2009; Westerink, Opdam, Rooij, & Steingröver, 2017; Wu, 2013).

However, landscape planning and governance research will also need to consider the potential pitfalls and challenges of using the concept of NBS in its activities. These challenges may concern the conceptual vagueness of the term and its divergent definitions, the still unknown usefulness of the term in public discourses, and the risk of losing sight of longer-term, persisting problems when focusing predominantly on quick solutions for societal challenges. Furthermore, landscape planning and governance research should be aware of emerging criticism of NBS concept as overemphasizing a utilitarian perspective on nature which might promote exploitation and commodification (Nesshöver et al., 2017; Schröter et al., 2014). To address such concerns, the NBS concept will need to be applied gradually and carefully, framed within clear boundaries of existing legislative and cultural targets, norms and values (cf. Albert et al., 2017, including a

Table 1
Complementary contributions of landscape planning and governance research concerning the realization of nature-based solutions.

Potential contributions of landscape planning	Potential contributions of governance research
Key focus: Providing scientifically robust, practically salient and procedurally legitimate spatial information and facilitating joint exploration of societal challenges, NBS, alternative interventions, and their respective implications	Key focus: Providing insights on institutions and actors relevant for the implementation of NBS, and guidance on governance models for realizing preferred development strategies
Examples of potential contributions – To spatially assess water-related challenges and potential causes on the socio-ecological system – To show different paths of water resource planning and management and the trade-offs posed by those possible developments – To integrate individual actions such as natural water retention measures into comprehensive plans (e.g. river basin management plans, flood risk management plans) – To integrate arts and design in landscape development planning – To assess the diverse benefits and costs for divergent decision options and their potential impacts on ecosystem services – To develop actor-specific, spatial implementation concepts – To foster transdisciplinarity by co-identifying, co-designing, and co-implement strategies that support NBS as decision options together with stakeholders and local experts	Examples of potential contributions – To identify and assess social networks that affect the capacity to govern water – To explore stakeholders' interests, influence and interactions in a river basin – To understand drivers and barriers of the water governance systems to identify mechanisms for enabling system transformation – To provide knowledge about best practices of good water governance – To facilitate the potential of co-creation and co-innovation of governance and business models for funding and realizing NBS – To foster transdisciplinarity by collaborative problem framing, knowledge co-creation and re-integration of the created knowledge together with stakeholders and local experts

first step towards identifying relevant NBS criteria).

Box 1. Lahn river landscape case study.

A typical example of the challenges and opportunities for safeguarding, designing and realizing NBS in river landscapes is provided by the Lahn river, located in Hesse and Rhineland-Palatinate, Germany. Policy makers and stakeholders increasingly recognize the numerous challenges arising from the historic transformations of the Lahn river landscape, mainly the fact that part of the Lahn river has been straightened and dammed to serve as a federal waterway for navigation from the Rhine up to the city of Gießen. The substantial alterations of the river landscape have impaired linear patency, changed water regimes, and cut off historic floodplains from frequent flooding.

The Lahn is no longer used for cargo navigation while the uptake of technical infrastructure such as weirs and sluices requires substantial investments. The ecological quality of the Lahn river still remains far from the target of a good ecological status according to the Water Framework Directive. Restoring parts of the Lahn river are being discussed, but the changed context conditions such as settlement developments make a complete restoration of previous states impossible. At the same time, stakeholders such as a passenger shipping company and yacht owners intend to maintain the current conditions. Against this background, new solutions need to be explored for addressing the emerging challenges. A window of opportunity currently exists in that river restoration efforts are of high political topicality as reflected in the new government initiative to restore federal waterways in the blue ribbon program (blaues-band.bund.de).

NBS like the restoration of wetlands, the revitalization of floodplains, the transformation of the grey into green infrastructure, the protection of riparian flora, fauna and forest and the adaptation of land use practices, e.g. transforming farmland into grassland or planting buffer stripes may help to confront these challenges. They will not only produce ecological co-benefits, but also co-benefits for human well-being. Giving more space for the rivers alleviates the flood risk and improves flood protection (human security co-benefits), while enhancing flora and fauna improves conditions for recreation and psychological well-being (social and cultural co-benefits). Removing the barriers in the river would be a cost-effective alternative to dam and weir repairing measures (economic co-benefits). As with these NBS multiple ecosystem services are addressed, various interests of diverse stakeholder groups can be balanced.

For this approach becoming reality, some support for planning and governance is necessary. This is done by the interdisciplinary PlanSmart research group (www.plansmart.info) (supported by a research grant from the German Ministry of Education and Research BMBF), which, in collaboration with the Integrated EU LIFE Project “Living Lahn” (www.lila-livinglahn.de), provides scientifically sound decision-support to design strategies for sustainable development of the Lahn river landscape with a particular focus on NBS. PlanSmart collaborates closely with experts, decision-makers, stakeholders and citizens in the Lahn region to co-identify alternative river landscape development scenarios, to explore their respective implications, and suggest innovative implementation concepts and funding strategies. In particular, PlanSmart provides empirical evidence of the ecological, social and economic effects of scenarios (including NBS options) and explores suitable governance and business models for implementation.

To implement its research program, PlanSmart has established a LahnLab (see Fig. 4) as a transdisciplinary platform based on the concept of real-world experiments (Groß, Hoffmann-Riem, & Krohn, 2005) that can function as a boundary object in a transdisciplinary research process appearing as a reference space for diverse actors and disciplines to exchange and correspond their knowledge and thus promote societal learning. Within the LahnLab, a series of workshops are held to jointly concretize the LahnLab aims and methods, develop scenarios of future development pathways, to simulate scenario effects on river landscape development, to explore likely impacts of the scenarios on societal challenges and diverse ecosystem services, and to develop implementation concepts for realization of preferred scenarios. Focus areas between Wetzlar and Gießen with different actor constellations were selected to explore how NBS can be implemented.

Taken together, the LahnLab illustrates how planning and governance research for NBS can be provided in a transdisciplinary setting. The LahnLab outcome will be an enhanced understanding among local actors of strategic options for developing the Lahn river landscape, of implications of choosing NBS or technical alternatives, and of new governance and business models for implementation. This information can inform the formal decision-making process within the LiLa project. Scientifically, new understandings of the effects of alternative river development strategies, and new knowledge on theories and methods for integrative landscape planning and governance research will be developed.

4. Towards a research agenda

This paper introduces the concept of NBS exemplified at river basin management, highlights its potential to provide new incentives for implementing more sustainable landscape and catchment development, and emphasizes the key roles that landscape planning and governance research can assume in facilitating the co-identification, co-creation, co-exploration and co-implementation of respective strategies.

However, more research and practical experimentation will be needed to clarify which NBS might be employed ubiquitously and which need a place-based comparison with alternative approaches. Therefore, further scholarship is needed to more systematically and empirically exploit the complementary contributions that landscape planning and governance research can provide to face challenges such as climate change, water pollution, or access to clean water (in river basins as in our example). We propose a research approach that focuses on the need to develop relevant 1) system knowledge (context and biophysical setting of the river basin in our example), 2) target knowledge (land use development goals and e.g. pollutant target values in our example), and 3) transformation knowledge (about actions that lead to implementing these targets) (cf. Hirsch, Hadorn, Bradley, Pohl, Rist, & Wiesmann, 2006). Our research agenda is informed by early studies on NBS research needs (Eggermont et al., 2015; Kabisch et al., 2016; Nesshöver et al., 2017; Raymond et al., 2017). In more detail, this means:

1) Advancing system knowledge in the context of planning and governance research around NBS will involve identifying and synthesizing existing evidence on the effectiveness of NBS. This includes an assessment of the outcomes of both, NBS and technical alternatives, for challenges such as flooding, water shortage, water pollution, pollinator endangerment or extinction of species. Furthermore, co-benefits and costs of NBS will be identified and assessed using multimetric indicators such as recreation potentials, water retention, and

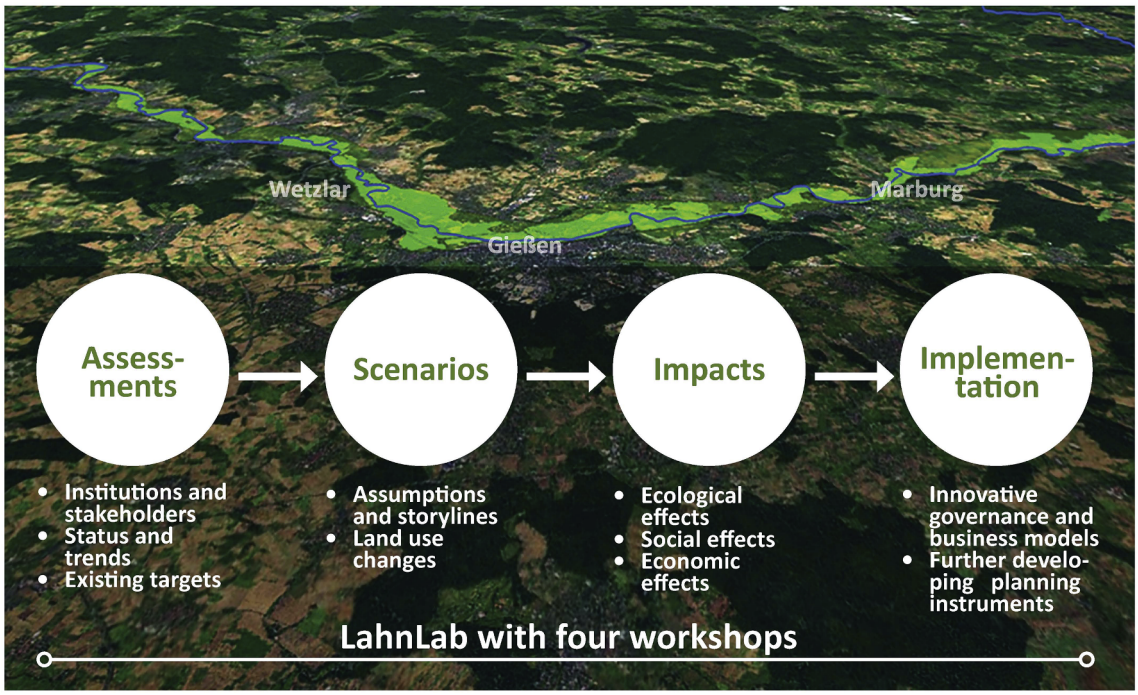

Fig. 4. LahnLab and workshops for the transdisciplinary development and exploration of scenarios for future river landscape development including NBS and respective implementation options. Background image: ArcGIS Online World Imagery Basemap 2018.

biodiversity, also acknowledging multiple value dimensions (cf. Pascual et al., 2017). Finally, society-relevant assessments of NBS need to be conducted, for example to identify those groups of actors or individuals that either benefit from or be harmed by a NBS (Raymond et al., 2017).

2) Research needs in the field of target knowledge concerning NBS planning and governance refers to how planning processes can be designed and embedded in a wider governance structure in ways that a) support the co-generation of relevant knowledge and b) develop stewardship for nature at the specific location. This requires a better understanding of how solution-oriented, transdisciplinary planning processes can be facilitated to make use of divergent knowledge systems. Improved methods are needed to evaluate integrated, landscape-level plans for NBS in ways that are useful for decision-support and not too resource-intensive to be applied in practice. Further study needs to address options for joint planning approaches that combine sectoral planning instruments. Finally, planning experiments and serious games can help exploring the practicality and impacts of proposed NBS strategies.
3) In the field of transformation knowledge, an enhanced understanding is crucial concerning appropriate funding, governance and business models for sustainably implementing NBS in different governance contexts and actor constellations. Synthesizing evidence on supportive governance and business models for different NBS can help identifying best practice examples (cf. Raymond et al., 2017). Approaches for governing NBS need to be developed that ensure a fair distribution of benefits and costs, i.e. through multi-criteria analysis and a weighting process between competing interests. Furthermore, approaches for harnessing the complementary roles of state, business and civil-society in NBS implementation need to be developed and explored, and finally, opportunities and approaches for relevant education and social learning need to be identified and used.

Taken together, the transdisciplinary field of landscape planning and governance research around NBS opens up promising new opportunities to engage diverse stakeholders in informed discussions concerning preferred visions for the future of our landscapes. We propose that landscape and urban planners should make use of these opportunities, and to coordinate our efforts in order to learn from and build upon previous experience.

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