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Review

Knowledge gaps and future research needs for assessing the non-market benefits of Nature-Based Solutions and Nature-Based Solution-like strategies

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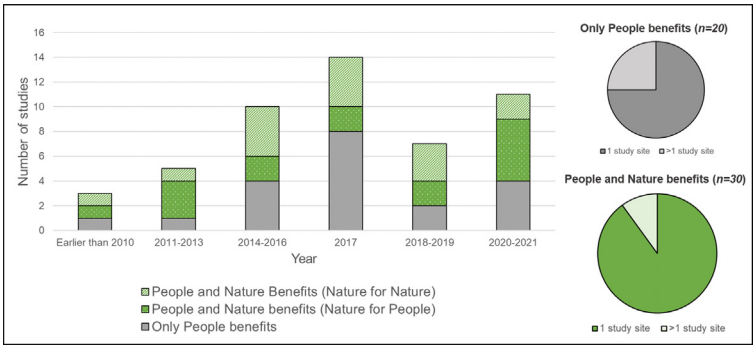
HIGHLIGHTS

- Review of studies using stated preference to assess non-market people benefits.
- Current literature relates to "non-NBS-specific" assessment methods.
- Replicability and up-scaling of methods are not prioritized.
- Integration of benefits for nature is often not considered in the assessments.
- Future research should focus on holistic and replicable NBS benefit quantification.

GRAPHICAL ABSTRACT



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ABSTRACT

Nature-Based Solutions (NBS) can be defined as solutions based on natural processes that meet societal challenges and simultaneously provide human well-being and biodiversity benefits. These solutions are envisioned to contribute to operationalizing sustainable development strategies, especially in the context of adaptation to climate change (e.g. flood risk reduction). In order to quantify NBS performance, ease their uptake and advocate for them as alternatives to "business-as-usual" infrastructures, a comprehensive, holistic valuation of their multiple benefits (multiple advantages and disadvantages) is needed. This entails quantifying non-market benefits for people and nature in addition to determining the (direct) cost-benefit of the risk-reduction measure. Despite the importance given to the assessment of non-tangible benefits for people and nature in the literature, systematic data collection on these dimensions seems to be missing. This study reviews publications that used stated preference methods to assess non-market human benefits of NBS and NBS-like strategies. Its aim is to highlight any biases or knowledge gaps in this kind of evaluation. Our results show that the valuation of non-tangible benefits of NBS (e.g. increased recreation and well-being, enhanced biodiversity) still suffers from a lack of common framing. Despite some steps being taken on enabling interconnected benefit assessments, unexploited opportunities concerning the integrated assessment of non-market human and nature benefits predominate. Moreover, the research to-date appears based on a case-to-case approach, and thus a shared holistic method does not emerge from the present literature, potentially delaying the uptake of NBS. We argue that future research could minimize missed opportunities by focusing on and systematically applying holistic benefits assessments. Methods based on stated preference surveys may help to ensure holistic approaches are taken, as well as contributing to their replicability and application when upscaling NBS.

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Contents

1. Introduction

In recent years, the concept of natural capital, defined as the world's stocks of natural resources, including geology, air, soils, water and all living organisms, has been emerging, reflecting the acknowledgement that environmental systems play a fundamental role in determining a country's economic state and social well-being (EEA, 2015). In Europe and worldwide, the natural capital is under an ever-increasing pressure, and as we struggle to solve environmental, social and economic challenges, the need for transitioning to a sustainable use of natural resources is now more evident than ever. One of the strategies believed to be key for the operationalization of sustainable development is Nature-Based Solutions (NBS) (IUCN, 2020).

NBS are defined as strategies based on natural processes, which meet societal challenges and simultaneously provide human well-being and biodiversity benefits (European Commission, 2015; IUCN, 2012). The European Commission and the IUCN describe NBS slightly differently, with the European Commission defining them as "actions inspired or supported by nature", while the IUCN frames them as "actions to protect, sustainably manage, and restore natural or modified ecosystems". However, they both agree that what makes NBS particularly attractive is their ability to deliver multiple benefits. In fact, NBS not only provide direct solutions to present challenges (like climate change adaptation), but also enhance the spatial quality of the surrounding area in many direct and indirect ways (e.g. increased green areas, cleaner air, more recreation possibilities). Since their concept was coined, NBS have been prioritized in international environmental policy agendas (Cohen-Shacham et al., 2016), disaster risk management (World Bank, 2017) and research programs such as the European Union's (EU) Horizon 2020 (European Commission, 2015).

Despite this, the widespread application of NBS still appears to be lacking, due in part to the perceived high costs associated with their operationalization and maintenance (Jia et al., 2017; Qiu et al., 2020). Thus, a fundamental step for the successful uptake and implementation of NBS as alternatives to gray infrastructure is the holistic valuation of their multiple advantages and disadvantages, i.e. not only traditional valuation of tangible assets, but also quantification of non-market, non-tangible benefits, such as the ones affecting human well-being or biodiversity status. Economic valuation of non-tangible benefits is a crucial tool to ensure that stakeholders are aware of the total value of NBS and take this into consideration during decision-making. Recent studies have shown that despite the challenges of monetization, the inclusion of non-market benefits in cost-benefit analyses improves the economic feasibility of NBS and increases policy makers' awareness of these solutions (Bayulken et al., 2021; Venkataramanan et al., 2020). A more comprehensive benefit valuation, focusing on including also non-market benefits, could thus contribute to speeding up NBS uptake (Alves et al., 2019; Hanson et al., 2020; Sharifi et al., 2021; Teotónio et al., 2021). Given the strategic importance of NBS uptake for the achievement of sustainable adaptation, the European Commission has funded a series of projects for planning, evaluating and implementing NBS, including their upscaling outside of cities, in which holistic assessments occupy a key role (European Commission, 2015).

The economic quantification of non-tangible benefits can be challenging. When it comes to quantitatively assessing benefits that do not fit any market, they are quantified indirectly using revealed preference (RP) methods (e.g. travel cost/time and house prices) (Koetse et al., 2015). However, for non-tangible benefits that do not have any related markets, stated preference (SP) methods are the most prominently used strategies in the literature. Multiple variations of SP methods exist, but the most common approaches are contingent valuation (CV), in which respondents are asked whether they would choose a proposed option at a specified price, and choice experiments (CE) methods, where respondents have to state their preference among two or more multi-attribute options (Arrow et al., 1993; Johnston et al., 2017).

While SP methods allow us to establish a monetary valuation of non-tangible benefits, how they are presented within the assessment (questions posed) is also fundamental for ensuring a successful and holistic benefit quantification. There have been a number of studies focused on describing the best approach for the assessment of non-tangible benefits of NBS (Díaz et al., 2018; Hanson et al., 2020; IUCN, 2020; Norgaard, 2010; Raymond et al., 2017). Ideally, the valuation of non-tangible benefits (e.g. increased recreation and well-being, enhanced biodiversity) should extend across the three impact domains of NBS: namely the economic, environmental and social domains, as well as their interconnections. Ensuring these assessments are truly integrated should contribute to a more favorable cost-benefit analysis of NBS, and also ultimately reduce the potential need (and related costs) for fixing lost opportunities in the long run, e.g. incorporating nature-enhancing aspects once the risk reduction strategy is already in place.

Despite numerous recommendations – and associated tools developed to aid such benefits quantification (e.g. Benefits of SuDS Tool, O'Donnell et al., 2018; Blue-Green Cities toolbox, Mant et al., 2013) – recent studies point out that biases and gaps still remain regarding the evaluation of non-tangible NBS benefits (Choi et al., 2021; Hanson et al., 2020). Included among the highlighted gaps, for example, is a lack of stakeholder participation in the assessment of multiple benefits of NBS, and the need for improving methods for assessing especially socio- and ecological benefits (Ruangpan et al., 2019). Moreover, systematic data collection on the human dimensions (e.g. increased physical and psychological well-being, preferences and perceptions) of NBS and NBS-like strategies seems to be missing, and SP methods have been suggested as useful tools to fill this gap (Venkataramanan et al., 2020).

SP methods already have a predominant role in the estimation of non-use values, and are increasingly used as a fundamental support for the systematic assessment of NBS benefits. However, previous reviews on this topic still lack a more comprehensive analysis focusing on the

implementation of SP methods beyond their theoretical consideration. Previous reviews on the assessment of NBS benefits have mainly focused either on structured analyses of impacts (Castellanos et al., 2020; Choi et al., 2021; Din Dar et al., 2021; Sharifi et al., 2021), or on studying the implementation and monitoring of solutions in specific settings, such as large-scale NBS against hydro-meteorological risks (Ruangpan et al., 2019), urban NBS in policy-making (Dumitru et al., 2020) or in crisis contexts (Bayulken et al., 2021). With regards to reviews specifically examining methodologies for the quantification of non-tangible NBS benefits, studies were found on the perception of NBS (Venkataramanan et al., 2020), on the obstacles and progresses of NBS financing (Hagedoorn et al., 2021; Teotónio et al., 2021; Toxopeus and Polzin, 2021), and on the inclusion of environmental justice dimensions (Pineda-Pinto et al., 2021). However, no comprehensive assessment on the usage of SP methods across NBS typologies emerged. A comprehensive assessment may help establish how SP methods have been previously used to assess non-tangible benefits of NBS (and NBS-like strategies) and whether they align with recommendations in the literature.

A review of SP studies applied to NBS could be the starting point to investigate the state-of-the-art regarding the quantification of non-market NBS benefits for people, as well as their interlinkage with nature benefits. By using the term people benefits, we mean the collection of NBS impacts that have people as final, direct beneficiaries, i.e. increased recreation, increased psychological and physical well-being, greater economic opportunities. The widely investigated benefits known as Ecosystem Services (ESS) are here considered as a subgroup within people benefits, as they are used to define how ecosystem structure and function contributes to supporting human well-being (e.g. food provision, climate regulation), without encompassing all of the possible impacts on people's lives (Raymond et al., 2017). In addition to people benefits, there are nature benefits, which are the NBS impacts that directly benefit nature, assessed independently from whichever effect they may have on people, i.e. habitat restoration (habitat quantity), improved habitat quality (e.g. increase in number of species). Incorporation of nature enhancing elements (i.e. for nature, and not primarily as ESS for human benefit) is critical to ensure that the design of NBS will maximize its benefits for nature (Lemaire et al., 2021), which could be costly to adapt if not considered initially.

This study aims to deliver an overview on how intangible benefits provided by NBS, or NBS-like strategies, are quantified, with the following specific objectives: (i) review publications that used SP methods for assessing the non-market people benefits of NBS, in order to highlight any biases or knowledge gaps in this type of evaluation, and (ii) based on these findings, highlight improvements for future research. We include in our research both studies that focus on NBS as concrete assessments of a particular solution at a specific site, and studies that are aimed more at quantifying the benefits of implementing strategies that promote the concepts of NBS, denoted NBS-like strategies. We cover both these types of studies since both offer an insight into the mindset behind the current assessment of these solutions. Specifically, the research questions we are focusing on encompass: How are SP methods currently used for assessing non-market people benefits of NBS and NBS-like strategies? Can SP methods be used to also integrate the assessment of nature benefits? Is there a systematic SP approach that could form the basis of replicable benefit assessments? In answering these questions, we aim to shed light on the current state-of-the-art with respect to the assessment of non-tangible benefits for NBS, and indicate how future research should advance to fill the identified gaps required to optimize the holistic valuation of the multiple benefits of NBS.

2. Materials and methods

This study is based on a structured literature review on the assessment of non-market benefits for NBS. Our aim was to include a wide range of peer-reviewed scientific publications from all over the world, where it is worth mentioning that the term NBS is fairly recent, and mostly used in a European context; the same concept takes on different names in different geographical regions or research areas, e.g. Water Sensitive Urban Design (WSUD), Blue-Green Infrastructure (BGI) (Fletcher et al., 2015; Ruangpan et al., 2019). Consequently, when setting out to screen the literature, the inclusion of studies on other NBS-like concepts, which are not defined using the keyword NBS but are carrying out the same kind of strategy – namely solving societal challenges while providing human well-being and biodiversity benefits – was deemed reasonable. For this reason, the term "nature-inspired strategies" will be used in this paper when referring to both NBS and NBS-like strategies.

A paper search was conducted in November and December 2020 using the electronic journal database Web of Science. The search protocol implemented was:

- TOPIC:
  - ("Nature-based solutions" OR "Nature based solutions" OR "nature-based" OR "nature based" OR "Green Infrastructure" OR "Blue-Green Infrastructure")
  - AND ("benefits" OR "ecosystem services")
  - AND ("valuation" OR "value" OR "stated preference" OR "contingent valuation" OR "dichotomous choice" OR "choice experiment" OR "stated choice")
- OR TITLE:
  - ("Nature-based solutions" OR "Nature based solutions" OR "nature-based" OR "nature based" OR "Green Infrastructure" OR "Blue-Green Infrastructure" OR "blue amenities" OR "terrestrial water" OR "watershed" OR "wetlands" OR "open space" OR "water assets" OR "water bodies" OR "canals" OR "lakes" OR "green" OR "greenbelt" OR "green roof" OR "garden" OR "park" OR "forest" OR "water" OR "water quality" OR "wetland")
  - AND ("benefits" OR "ecosystem services")
  - AND ("valuation" OR "value" OR "stated preference" OR "contingent valuation" OR "dichotomous choice" OR "choice experiment" OR "stated choice").

The search resulted in 585 articles published in scientific journals. In a first step, duplicate and retracted articles were removed. In addition, studies performed before the year 2000 ($n = 10$) were excluded to ensure that the selection was up-to date.

The remaining studies were filtered based on the following criteria:

- Must be a primary study, i.e. a study collecting data directly from the respondents through questionnaires and/or interviews;
- The study had to be assessing an NBS or a nature-inspired adaptation strategy. For example, a choice experiment for the implementation of passive forest restoration in a Natural Park was selected for further analysis. On the other hand, a survey on the willingness-to-pay (WTP) for water quality improvement *not* based on a nature-based/green infrastructure approach was not included in the analysis.
- Use a SP method to assess the non-market people benefits for nature-inspired strategies.

The outcome of the last filtering was a final sample of 50 papers. The full text of these papers was read, and their content was analyzed through the use of a standardized data extraction sheet (see Supplementary Material). The extraction sheet was designed to answer the research questions; to ensure that the review process was consistent, various meetings between co-authors were held during the phase of data collection. The outcome of this process was data classified into standardized definitions that can be grouped into two main sections:

1) Descriptive characteristics (e.g. study year, number of study sites, SP method used, type of nature-based strategy). These data were registered to provide a context for the study and to examine the overall trends in the literature. In particular, the number of case studies was also used as a proxy to determine whether the SP method applied in the paper was deployed in a way that considered and/or allowed for its replication in different study sites.
2) Quantified non-market benefits (e.g. how people benefits are assessed, if and how nature benefits are assessed). As this study is based on

literature assessing non-tangible benefits for humans, all the selected papers quantified people benefits in some way. Specifically, as the examined studies carried out their assessment through SP methods, we focused on their valuation questions in order to find out which non-market benefits they were targeting for quantification. Both CV and CE studies were reviewed; in the case of CE methods, the valuation question to the respondents may not be direct, but rather implicit within the choice cards presented (e.g. select preference from option given). Note that, in order to present more clearly the classification process as applied in this study, choice card examples have been summarized as questions.

The quantified people benefits were sorted in the following groups: regulating ESS, provisioning ESS, supporting ESS, cultural ESS, integrated ESS, recreation, economic benefits, accessibility, human well-being, and nonspecific benefits (Table 1, Supplementary Material). For example, if the respondents were asked to value the NBS based on a provided ESS (e.g. provision of clean water, through the question "How much would you be willing to pay for the proposed strategy to improve water quality?"), the study was classified as assessing ESS benefits (e.g. regulating ESS) (Ramajo-Hernández and del Saz-Salazar, 2012). If respondents were asked to value the NBS based on the recreation potential they receive from the area (e.g. through answering the question "How much would you be willing to pay for a trip/ticket to the area?"), the study was classified as assessing recreation benefits (e.g. Mejía and Brandt, 2017; Mishra, 2017). If the study asked for the valuation of, as an example, both recreation and provisioning ESS benefits of the nature-inspired strategy, both labels were then applied to it during the classification. In the case of the examined study not directly stating the human benefit(s) to be valued by the respondents, the study was classified as assessing a "nonspecific benefit". Table 1 presents a more detailed overview for all people benefits quantified in the literature reviewed here, including a brief description of which specific benefits are included within each category.

Furthermore, we documented whether the selected studies assessed only people benefits, or if they took into consideration nature benefits as well. A study was classified as assessing also nature benefits if the respondents were asked to value the NBS based on at least one nature benefit generated by the strategy. In this case, the possible entries for benefit quantification were: habitat quality, habitat quantity, biodiversity, species abundance, extent of protected area, management of protected area and landscape structure. For example, if respondents were asked to value the strategy based on the increase in the number of species it will support (e.g. through the question "How much would you value this proposed strategy, if it increased the number of migratory bird species in the area?"), the study was classified as assessing a "biodiversity benefit" (e.g. Faccioli et al., 2015; Petcharat et al., 2020). If respondents were asked to give a value to the increase in the extent of protected land (e.g. through the question "Would you be willing to pay more taxes to allow for the protection of larger natural areas?"), the study was classified as assessing an "extent of protected area benefit" (e.g. Hynes et al., 2021; Valasiuk et al., 2018). Also in this case, if the study asked for the valuation of more than one identified nature benefit, more labels were applied to it during classification. An overview for the classification labels regarding nature benefits can be found in Table 2.

Within this latter group of studies assessing both people and nature benefits, we classified how the examined publications investigated nature benefits, in terms of separation from people ("nature for nature" or "nature for people", i.e. ESS). This classification was once again based on the way the valuation questions were posed. If the studies were using questions taking an anthropocentric perspective on changes benefitting nature (e.g. "How much will you be willing to pay for a swimmable water quality?" or "Would you be willing to pay a ticket to visit a more diverse forest?") (Doherty et al., 2014; Liu et al., 2019), they were classified as quantifying "nature for people" benefits. On the other hand, studies asking the respondents for the value of a nature benefit independently from people's possible experience of these same benefits were classified as quantifying "nature for nature" benefits. Examples could be, "How much would you be willing to pay for conservation efforts on this marine area?" or "Would you be willing to donate for the enlargement of this no-entrance protected forest?" (De Valck et al., 2014; Gelcich et al., 2013). For a complete overview of the classification scheme and the full list of references for the literature review, see the Supplementary Material (Tables S1 to S4). Finally, for these studies assessing both people and nature benefits, we ran a last analysis to determine which of these benefits were quantified together, and how often these "pairings" were repeated.

Table 1
Scheme used for the classification of people benefits that were assessed in the reviewed studies, and examples of assessed benefits grouped under each label.

Quantified People benefits	Examples
Regulating ESS	Flood prevention, climate regulation, clean air, etc.
Provisioning ESS	Energy, food, transportation, etc.
Cultural ESS	Aesthetic appreciation; inspiration; spiritual; sense of place
Supporting ESS	Biological diversity maintenance, nutrient recycling, etc.
Nonspecific ESS	Assessment scenario mentions ESS provided by the NBS, but does not specify which one(s) in particular are being valued
Recreation	Recreation facilities, tourist attractions, size of the area that can be visited, increasing the recreational potential of the area
Economic benefits	Increase in property values; Increase in business opportunities
Accessibility	Distribution of green infrastructure/NBS in a certain area; Presence of paths/gates
Human well-being	Satisfaction with the experience in the NBS, enjoyment of the area, stress and worry decrease
Nonspecific benefits	The valuation scenario doesn't specify which human benefits are being valued

3. Results and analyses

3.1. Existing approaches for valuation of nature-inspired strategies

The screening process resulted in the selection of 50 papers for the more detailed review. Most of the studies (66 %) were published after 2016, with 2017 being the year where most of the selected papers were published (28 %). European nature-inspired projects were the most represented, constituting almost half (48 %) of the analyzed papers. 22 % of the projects were conducted in Asia, followed by North America, South America, then Africa and Oceania.

All the selected papers aimed to quantify the non-tangible benefits of a nature-inspired strategy, but only a few explicitly used the term "Nature-Based Solutions" (Derkzen et al., 2017; Reynaud et al., 2017). This could be a result of the difference in terms used across the world (Ruangpan et al., 2019). Moreover, a share of these articles pre-date the appearance of the term NBS, which was first described explicitly in 2008 (Hanson et al., 2020) and then further promoted by the IUCN and the EU research and innovation program Horizon 2020 later (European Commission, 2015; IUCN, 2012). Nevertheless, the overall literature on NBS has been reported as continually growing (Hanson et al., 2020; Ruangpan et al., 2019), but this growth does not seem to be related to growth in terms of research on the holistic quantification of non-tangible benefits for NBS.

3.1.1. Study design

A variety of nature-inspired strategies were examined in the selected studies, with the majority involving blue and/or green non-urban open space (Table 3). The studies were conducted on a range of different scales, with most of the strategies discussed appearing to be developed on a large scale. For example, older nature-inspired strategies focused on larger areas (e.g. natural parks, peri-urban open spaces). Smaller scale strategies deployed within urban areas seem to come into the picture at a later point of time, following the interest expressed by the EU Research and Innovation

Table 2
Scheme used for the classification of nature benefits that were assessed in the reviewed studies, and examples of assessed benefits grouped under each label.

Quantified Nature benefits	Examples
Habitat quality	Assessment of habitat functions; assessment of habitat quality indicators
Habitat quantity	Area and distribution of a certain habitat
Biodiversity	Number of species (species richness); gene pool assessment (genetic diversity); species composition
Species abundance	Number of species' individuals
Extent of protected area	Amount of protected land (e.g. as part of a Natural Park)
Management of protected area	Establishment of no-visit zones; launching of breeding programs
Landscape structure	Broader overview of landscape patterns: degree of habitat fragmentation, presence of different habitats/ecosystems, habitat diversification

agenda to deploy NBS to enhance sustainable urbanization (European Commission, 2015). The diversity of scales and types of nature-inspired strategies involved in the examined studies shows that the quantification of non-tangible benefits can be and has been conducted in a variety of contexts. Moreover, the knowledge resulting from these variety of studies is fundamental to be able to apply lessons learned to other NBS.

Notably, the SP method chosen is almost equally distributed between CV (54 %) and CE (46 %). The SP method used was registered to check for possible preferences regarding the approach to quantify NBS benefits. Given the even distribution of the methods, we can assume that there is not one clearly preferred approach in the examined literature. This reflects the literature's claims that both SP methods are relevant for the quantification of non-tangible use values of nature-inspired strategies (Johnston et al., 2017; Ndebele and Forgie, 2017), and that the choice of one over the other is made based on site-specific situations (e.g. cognitive burden to place on respondents, assessment of the totality of the benefits vs. individual attributes, etc.). Notably, all 50 selected papers chose the general population as the target group for their studies. Some focused on visitors (e.g. Mäntymaa et al., 2018; Pérez-Urrestarazu et al., 2017), others on residents (e.g. Reynaud et al., 2017; Sabyrbekov et al., 2020), but no targeted distribution to specific groups of, for example, experts or decision-makers was registered.

In regards to the characteristics of the studies, the majority of the papers (84 %) focused on one single study site only (e.g. Balderas Torres et al., 2015; López-Mosquera and Sánchez, 2011; Tyrväinen, 2001) (Fig. 1). The number of study sites in each paper was documented in order to examine whether the authors had an interest in or tried to apply the same quantification methods in different areas, and explore the replicability of their valuation approach. In one case (Bateman et al., 2011), this was explicitly listed as one of the goals of the paper. However, for the bulk of the reviewed cases, the studies did not seem designed with this in mind, i.e. to additionally explore the replicability of their methods, and instead focused on the creation of site-specific assessments. Using meta-analyses in order to transfer the findings of studies based on one study site can be a suitable option to upscale results. However, meta-analyses are dependent on the outcomes and assessed variables of primary studies, therefore their implementation can be impaired by primary studies basing their assessments on site-specific and non-standardized methods. This can force meta-analyses to rely on crude assumptions that in turn can lead to less precise estimations (Bockarjova et al., 2020).

Finally, it is important to point out that the choice related to number of study site depends of course on many other factors than just the testing of replicability, e.g. on budget or time restraints. Nevertheless, our findings seem to highlight a tendency in the literature to date to approach benefit quantification on a project-to-project basis in primary studies. Moreover, there appears to be a gap in research that strives for the creation of tools to quantitatively assess non-tangible benefits across different study sites.

3.1.2. Assessment of benefits

3.1.2.1. Types of benefits assessed. In a first step, the different types of benefits assessed in the sampled studies were analyzed in more detail. While some studies only assessed human benefits, 30 of the papers (60 %) also included nature benefits in their evaluation (Fig. 1). For example, in the study by De Valck et al. (2014), nature benefits such as the increase in biodiversity and diversification of habitat composition were recognized from the start as fundamental characteristics of the solution that were expected to influence the respondents' valuation. Therefore, they were assessed at the same time as, and in connection with, the people benefit of recreation. Notably, the studies including nature benefits are spread out rather evenly across the timeline, and there doesn't appear to have been a shift in the assessments' focus after the spread of the NBS concept. Overall, research appears to be integrating human and nature benefits within benefits assessments, which is a fundamental step in order to reach a properly integrated benefit quantification of NBS. However, there still seems to be some challenges related to pursuing an integrated approach, as indicated by the fact that almost half of the studies focus only on people benefits. This could be an issue, as inconsistent inclusion of nature benefits within SP assessments of non-market benefits could impair the integration of these benefits as a common practice in NBS evaluation.

3.1.2.2. Framing non-tangible benefits. Focusing first on the way nature benefits are assessed in the examined studies, our results show that half were quantified as "nature for people" benefits, while the other half as "nature for nature" benefits (Fig. 1). It is encouraging that 30 % of the total sample was not only quantifying nature benefits, but also doing so through a valuation scenario that was actually including improvements for nature regardless of their impact on humans, as it is expected from the implementation of nature-inspired strategies. However, the other half of the sample was only

Table 3
Descriptive characteristics of the analyzed studies ($n = 50$) according to NBS strategy type, including scale, number of studies and publication range.

Categories	Scale [study scale]	No. of studies [% of total]	Publication range [years]
Strategy types			
Building integrated greening	Street/building	3 [6 %]	2017–2020
Small-scale urban green/blue areas	Street/building; District/neighborhood	4 [8 %]	2015–2020
Public green areas (parks/gardens)	District/neighborhood; Metropolitan/city	9 [18 %]	2001–2020
Peri-urban open spaces	Metropolitan/city	7 [14 %]	2011–2020
Rural areas	Regional landscape	15 [30 %]	2007–2021
Protected natural areas (parks/reserves)	Regional landscape	12 [24 %]	2008–2020
Stated preference method used			
Contingent valuation (CV)	All	27 [54 %]	2001–2020
Choice experiment (CE)	All	23 [46 %]	2007–2021

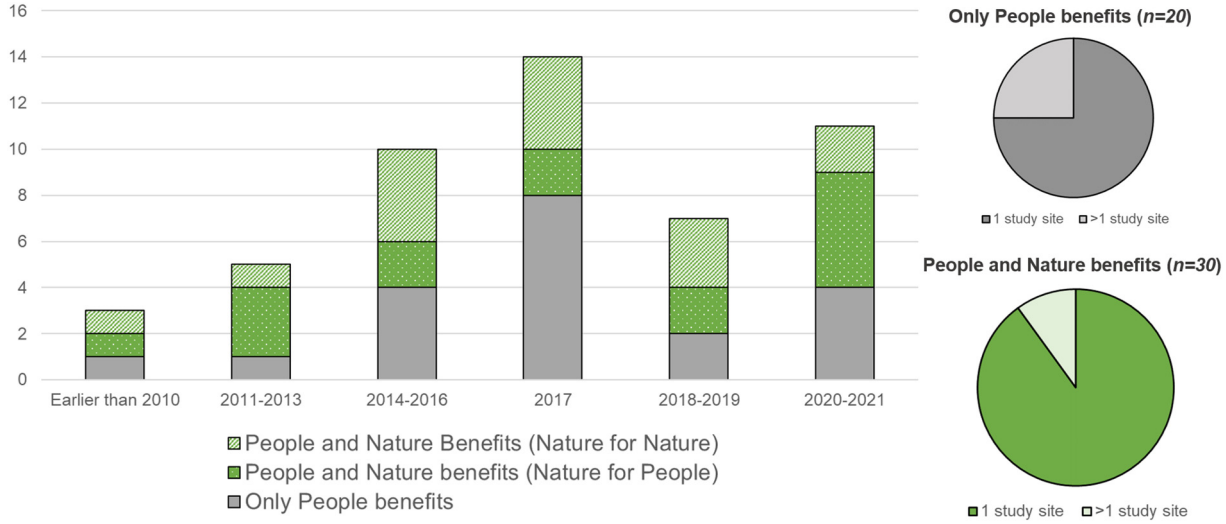

Fig. 1. Type of benefits assessed in the examined papers, grouped by publication year, including "only people" benefits (gray), and "people and nature" benefits. The latter are divided between "nature for people" (dotted) and "nature for nature" (striped) assessment of nature benefits. The pie charts additionally show how many papers had either one (darker gray and darker green) or more (lighter gray and lighter green) study sites.

looking at benefits from nature from an anthropocentric perspective. To a certain extent, this perspective can be useful for valuation, as benefits for people and for nature tend to overlap. For example, enhancing forest diversity can lead to an improvement of recreation activities and enjoyment of the area, and a consequent increase in the value associated to the changes by respondents. Yet, should the "nature for people" assessment become the predominant approach, it could normalize the misconception that the modifications created through NBS should ultimately prioritize human benefits. This could in turn lead to biased implementations, disproportionately favoring human activities (e.g. recreation) over improvements for nature. Therefore, assessment studies should attempt to include explicitly "nature for nature" quantification as independently as possible from human experience, in order to obtain a truly holistic valuation.

Fig. 2 shows more in detail how the assessed nature benefits were framed in the reviewed papers. The popularity of these two benefits well reflects the prominent position given to them in the guidelines for the robust assessment of NBS, such as the recent one by the European Commission (2021), given their centrality (specifically of biodiversity enhancement) in the NBS concept. Moreover, the presence of these benefits is possible in a wide range of NBS (e.g. from urban to rural contexts), while for example quantifying the benefits linked to the landscape structure requires a more specific type of NBS implementation. Finally, the quantification of benefits linked to a perceivable improvement of nature which may enhance the respondents' experience of the NBS is easier to determine through SP assessments.

Regarding the framing used for the assessment of people benefits, the quantification of recreation benefits seems to be the most widely applied throughout the sample. However, if considering all of the ESS sub-groups, ESS quantification appears to be the dominant way for assessing people benefits (Fig. 3). The ESS approach has various common points with the assessment of NBS benefits, e.g. both use indicators, monetary and non-monetary valuation techniques, and both link ecosystems to socio-economic systems, and can be a useful tool for people benefits quantification. Nevertheless, ESS-based quantifications are being criticized for relying on a framework that is only one of the many ways we understand ecosystems, being implemented on a project-by-project basis rather than at a greater scale, and failing to engage perspectives from social sciences and from stakeholders (Díaz et al., 2018; Norgaard, 2010; Raymond et al.,

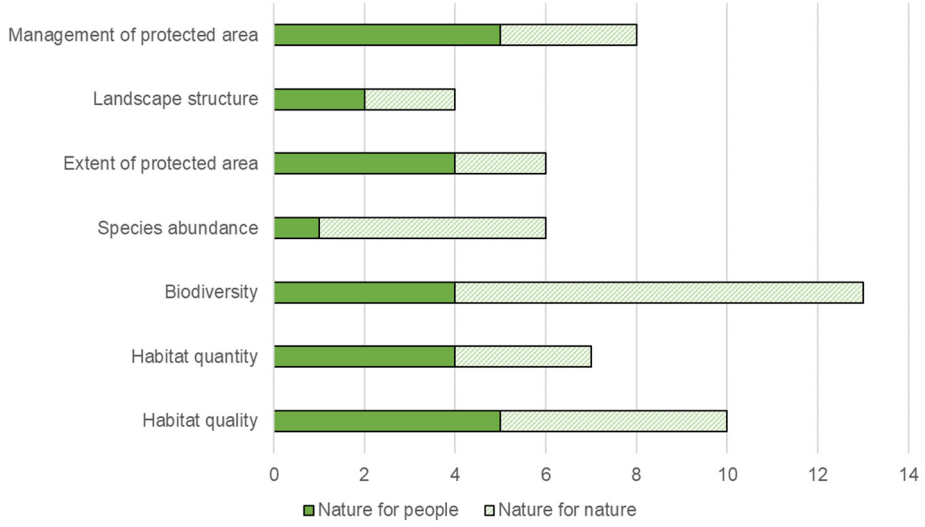

Fig. 2. Overview for the assessment of nature benefits across benefit types ($n = 30$), including benefits quantified as "nature for people" (darker green) and as "nature for nature" (striped lighter green).

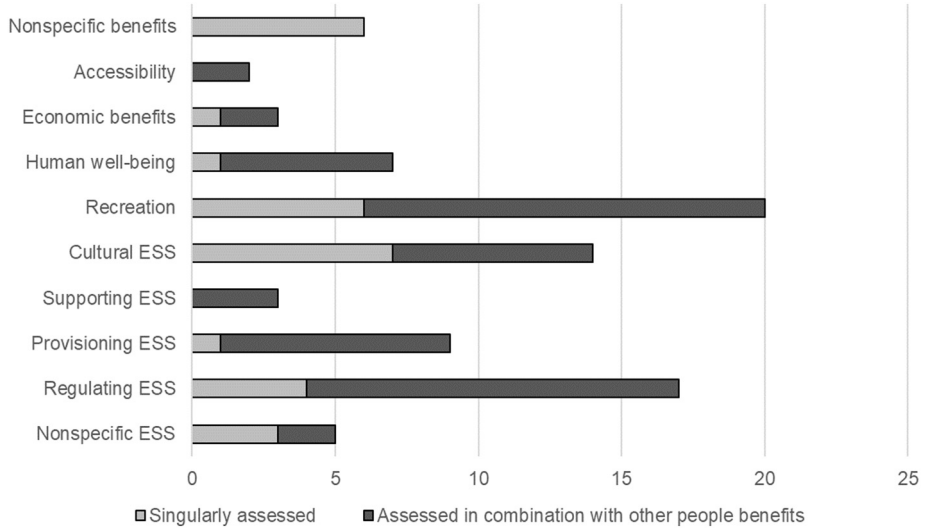

Fig. 3. Overview for people benefits that were assessed singularly (light gray) or in combination with other people benefits (dark gray), across benefit types ($n = 50$).

2017). Therefore, relying only on the assessment of ESS may result in an incomplete evaluation of the NBS benefits and a failure to identify potential for adverse impacts as a result of taking a fragmented approach to the valuation. For example, some studies were found focusing mostly on the benefits of enhanced ESS (mostly provisioning and regulating) of new green areas, without further exploring the possibility of the examined strategies benefitting nature as well. It is not surprising that regulating and provisioning ESS are extensively reported in the literature, as they include some of the services that are most directly linked to risk reduction and human livelihoods (e.g. flood risk reduction, wood provisioning, pollutants removal, food production, etc.). The quantification of these impacts is fundamental to support the use of NBS as alternatives to business-as-usual strategies. Nevertheless, downplaying the effects of NBS on nature may not only negatively affect the cost-benefit assessment of the strategy, but also miss the opportunity to consider different approaches to the solution. For example, by integrating more biodiversity enhancing areas or ensuring that the green area is planned in a way that is not only beneficial for people (i.e. ESS, recreation, and well-being) but also for nature (e.g. preventing degradation of nature at the expense of improving human benefits). Including such benefits and showing their potential value is thus an essential step to support holistic NBS implementation.

However, an ESS-valuation per se is not necessarily an option unsuited for the quantification of NBS benefits. For example, Reynaud et al. (2017) created a valuation scenario that included all of the aspects targeted by their examined NBS solution, i.e. risk reduction, and social and biodiversity benefits. The targeted people benefits were classified as ESS, but they were not treated as isolated impacts; on the contrary, the authors created a CV scenario that highlighted how the three components of the project fed off and interacted with each other to create integrated benefits. For example, they underline how having a green park would offer the same flood risk reduction (regulating ESS) as a gray infrastructure solution, but emphasize the additional benefits in terms of recreation and biodiversity benefits with the green solution. Further positive examples encompass studies that address various sub-groups of ESS and include other people benefits such as accessibility or human well-being (López-Mosquera and Sánchez, 2011; Sirina et al., 2017). Overall, if properly integrated with the evaluation of benefits from other perspectives (e.g. not only anthropocentric, but also focusing on benefits for nature), ESS assessments can be a valuable tool for the quantification of nature-inspired strategies' non-tangible benefits.

Aside from the valuation of ESS (with an emphasis on regulating ESS), our review also showed a tendency of the SP assessment for non-market benefits of NBS to rely heavily on the quantification of recreation benefits (Fig. 3). The reliance on recreation assessments could be partially explained by the fact SP assessments are particularly well suited for the quantification of these benefits (which are familiar, directly impacting the respondents and easy to create a valuation scenario for), as extensive coverage in the literature shows (Faccioli et al., 2015; Nielsen et al., 2007; Tyrväinen et al., 2014). Moreover, the assessment of these benefits is of great interest for the management of NBS implemented in touristic destinations, as it was the case in several of the reviewed publications, e.g. Ruka-Kuusamo winter sports area (Tyrväinen et al., 2014) or the Athalassa National Forest Park (Karanikola et al., 2017). Despite recreational benefits being a major component for enhancing the human well-being benefits of NBS, the quantification of nature-inspired strategies through valuation scenarios centering on human experience alone (e.g. "How much would you pay for experiencing this change/improvement?") can be limiting. In some cases, benefits for visitors and for biodiversity overlap, e.g. greater variety of ecosystems and species, larger green areas, etc. However, in other cases, if the NBS is assessed from a purely recreational perspective, some "nature for nature" improvements could be seen as negative changes (e.g. greater amount of deadwood or areas with limited access for people), contributing to lower valuations and a less positive cost-benefit assessment in total. Therefore, it is important for future valuations of NBS benefits to clearly articulate the aim and purpose of these strategies, in order to ensure the quantification of benefits integrates all of the impact areas of the solutions without any biases. A possible strategy to enable this is to supplement the evaluation method with the results of scientific assessment tools (e.g. ecological models, risk assessment analyses), which could show the respondents the most likely outcomes of the proposed strategies (as done in e.g. Derkzen et al., 2017). This procedure may be particularly effective in bringing to light the long-term effects of NBS, which often include "nature for nature" benefits (e.g. changes in the habitats, increase of a species' population numbers) and may be more difficult for the respondents to envision.

However, it should be noted that even with an unbiased presentation of NBS effects, trade-offs are inevitable among the different benefits of NBS (Alves et al., 2020). Moreover, the quantification of said trade-offs is especially challenging due to the varied perspectives of stakeholders, the multiple time scales of assessment and influence of other factors (European Commission, 2021). At the same time, their detection and analysis are key to achieve a holistic evaluation of NBS. Therefore, there is a need to reach a balance between establishing priorities among the benefits to evaluate and ensuring a holistic assessment of all possible benefits is undertaken (i.e. the risk reduction benefit should not be compromised, but the under prioritization of nature and people benefits should be avoided) (Alves et al., 2020). To achieve this complex balance, various studies suggest different approaches, from a thorough analysis of the trade-offs between costs, risk reduction and benefit enhancement (European Commission, 2021), to strengthening the involvement of citizens and private

actors (Dushkova and Haase, 2020). Moreover, sufficient evidence to clearly define NBS trade-offs is still needed (Alves et al., 2020; Dushkova and Haase, 2020; European Commission, 2021), and SP assessments could offer a relevant contribution to an evidence base gathered through direct interaction with various stakeholders.

Overall, and in the words of Hanson et al. (2020), research on the quantification of NBS and their benefits seems to be stuck on using an "older concepts toolbox" (e.g. quantification of ESS), passed down from concepts developed earlier such as green infrastructure or valuation of recreational benefits. As much as these incremental steps (i.e. building upon already established concepts) has previously worked to facilitate and promote the NBS approach within the scientific sphere, this compartmentalized "toolbox" is in danger of becoming more of a barrier when trying to holistically assess the benefits of NBS and expand their uptake in other contexts. Nonetheless, we have also seen how new assessment approaches are starting to emerge by effectively combining the quantification of the three areas of impact of NBS (i.e. within the economic, social and environmental domains). On the one hand, several of the reviewed studies strived to integrate all of these impact areas in their assessments by presenting all the expected impacts to the respondents, as discussed previously for Reynaud et al. (2017). On the other hand, some publications have utilized a more general valuation question regarding the impacts of the strategy. The latter refers to the approach that was labeled as "nonspecific benefits" within the context of this study. The publications using it have presented the implemented solutions and their impacts, and then let the respondents value them, i.e. asking valuation questions such as "How much will you be willing to pay for the implementation of the presented solution?" (e.g. Collins et al., 2017; Derkzen et al., 2017; Nielsen et al., 2007; Wilker and Gruehn, 2017). This broader approach does not focus the respondent's valuation on specific impacts, thereby avoiding reducing the assessment of the entire nature-inspired strategy to the valuation of a single aspect, or a small selected group of its benefits (e.g. only water provisioning services). At the same time, this approach is more susceptible to the knowledge limits of the respondent, and therefore also in this case, the NBS's overarching goals and expected positive impacts need to be clearly stated and explained in the valuation scenario.

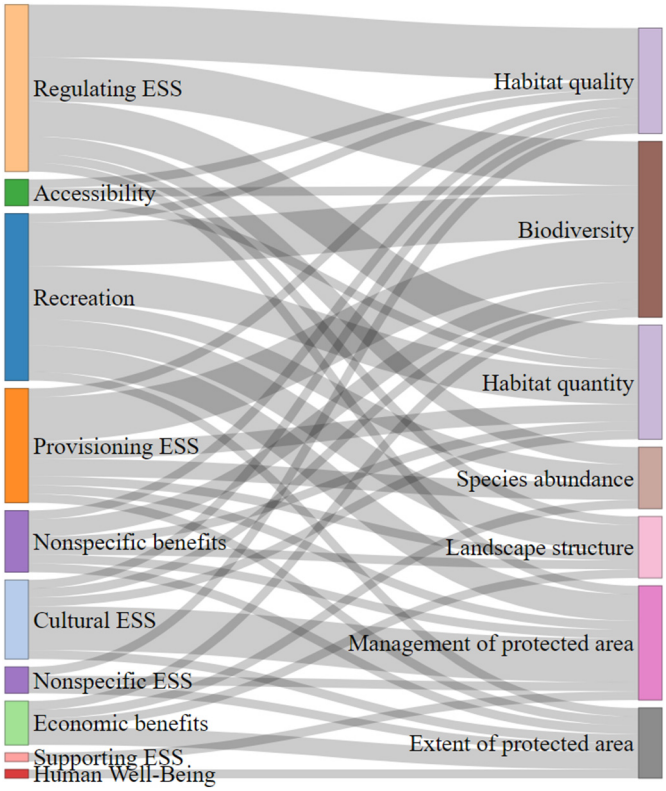

Fig. 4. Sankey diagram showing the relations between the assessed people (listed on the left-hand axis) and nature benefits (right-hand axis) for all of the analyzed benefit types. The higher the number of papers assessing two benefits together, the thicker the line connecting them. Note that the maximum line thickness symbolizes 6 papers.

3.1.2.3. Assessing interlinkages between people and nature benefits. Finally, for those publications where both people and nature benefits were valued together, we further examined which of these benefits were typically quantified together. Based on our initial analyses, the people indicators assessed most were recreation, followed by regulating, provisioning and cultural ESS (see Fig. 3). And for the nature indicators, these were biodiversity, habitat quality, and management of the protected area (Fig. 2). Fig. 4 schematizes the number of publications in which the chosen benefits were assessed together, where the thickness of the lines is proportional to the number of articles that quantify the connected benefits. This last analysis is based on a subset of the publications reviewed here ($n = 30$, i.e. the number of reviewed articles assessing both nature and people benefits); nevertheless, the highlighted connections offer some insights into how previous SP studies have paired up the assessment of people and nature benefits, in the absence of a predefined valuation framework.

Regulating and provisioning ESS appear to have a similarly strong connection to the valuation of biodiversity, but differ in their relationship to habitat quality assessment, which is for the most part quantified together with regulating ESS (Fig. 4). This latter connection appears to be particularly strong in nature-inspired solutions focusing on water-related risk reduction (e.g. solutions to contrast hydro-meteorological risks, such as cloudbursts or floods). When quantifying regulating ESS such as flood risk reduction and improvement of water quality, extending the valuation scenario to include the benefit of improved habitat quality appeared to be a sensible choice for various studies (e.g. Ando et al., 2020; Bateman et al., 2011; Ramajo-Hernández and del Saz-Salazar, 2012). As for the recreation benefits, they appear to be most often quantified together with biodiversity benefits, followed by habitat quantity (Fig. 4). The strong relation between cultural ESS and management of protected area benefits is most likely linked to the fact that cultural ESS were mainly assessed in study sites of particular relevance for visitors, i.e. natural parks and/or touristic destinations. In these contexts, the most common objective for the nature benefit quantification was to ascertain the positive impacts of managing (including actions such as maintaining, protecting and restoring) the NBS area and its characteristics (Liu et al., 2019; Sato et al., 2017; Thapa et al., 2020).

Benefits that can be intuitively paired can act as a solid starting point for the creation of a framework for the comprehensive assessment of NBS benefits. However, we believe that an assessment framework is needed that strives for a more objective and thus complete valuation, which permits the connection of all possible benefits, even those that may not be automatically linked. This way, even "unexpected" applications and impacts of nature-inspired strategies would be assessed, if qualitatively-based as a start (Pagano et al., 2019; Perrone et al., 2020), and not excluded a priori.

3.2. Path to implementation for a holistic quantification of NBS benefits

The results of our review disclose a number of gaps within the research on the assessment of non-market benefits of NBS and NBS-like strategies. First, the literature on this subject has been, until now, only partially integrating the spheres of human and nature benefits and has focused predominantly on single-case studies (Fig. 1). Moreover, despite offering a good insight into the use of the method, the past literature on the use of SP for the assessment of non-tangible benefits of nature-inspired strategies does not seem to offer a robust holistic framework that could be systematically applied to new NBS projects. In fact, most of the analyzed studies appeared to have different focuses and prioritization of benefits (compare Figs. 2, 3, 4).

These highlighted gaps in the current research can be particularly harmful in a planning context, where being able to obtain a holistic overview of a strategy's benefits is fundamental for designing and implementing a NBS fulfilling the desired impacts. Studies on the barriers for the implementation of NBS in such contexts name economic factors, together with a lack of knowledge and legal issues, as one of the main obstacles to NBS uptake (Wihlborg et al., 2019). Initiatives such as the COST Action Circularity City (Langergraber et al., 2021) aim at creating frameworks for the classification of NBS interventions and to achieve a better understanding of their concept in decision-making environments. However, as long as the benefits of nature-inspired solutions will be classified and valued as "separated silos", application of NBS will be challenged to comprehensively meet the various (and sometimes competing) goals within key international legislation and agendas (e.g. UN Sustainable Development Goals). Another key aspect of NBS valuation highlighted in the recent literature is the need for distancing from purely anthropocentric perspectives and advancing towards an approach that is as holistic as possible, from the planning to the evaluation phase (Bayulken et al., 2021; Pineda-Pinto et al., 2021). As we have also touched upon in our analyses, there seems to be an underlying tendency for treating the "nature for nature" benefits of NBS as an afterthought, i.e. after "solving" and implementing solutions beneficial for controlling water-related risks and working to ensure benefits to people are maximized (in terms of reducing water-related hazards). This trend risks compromising the actual impact of the solution, and at the same time can contribute to downplay the value of NBS, which would then again reinforce the perception of these solutions as economically infeasible or inconvenient. Here it is important to point out that our research does not mean to hold up the examined literature, which in various instances precedes the term "NBS" itself, against the newly emerged ideals. Instead, it strives to highlight how future primary data collection approaches, regarding the non-tangible benefits of nature-inspired strategies, need a change of pace that matches our growing knowledge on the said benefits.

We thus believe that research going forwards should focus on filling the identified gaps when conducting valuation studies in order to transition from a compartmentalized quantification to one that maximizes both the recognition for and the valuation of the multiple impacts stemming from nature-inspired strategies. If the array of NBS benefits is left unrecognized for long enough, it will be difficult in the future to advocate for these solutions in decision-making environments and justify their higher costs in respect to "business-as-usual", gray strategies (Jia et al., 2017; Qiu et al., 2020). It also risks a negative economic backlash, if implemented solutions must be adjusted once again, for example in what could become costly "restoration" activities, to undo unforeseen damage to local ecosystems.

Hence, we envision the path to implementation for a holistic quantification of NBS benefits to rely on an "enhanced" SP approach. SP methods have already been identified as a central tool for the assessment of non-tangible benefits of NBS by the literature. Moreover, they are widespread, supported by a large body of literature, and are the base on which broader meta-analyses are built upon (Arrow et al., 1993; Bockarjova et al., 2020; Johnston et al., 2017). All of these characteristics make a case for their continued use in the future. In particular, meta-studies would benefit from the application of an assessment framework that would produce comparable results from different locations.

Specifically, we envision any new methodological developments to focus on better transferability in addition to being holistic, as our study has highlighted a lack of studies carried out across different sites in the literature. A more transferable approach that can be applied across different sites could possibly uncover broader, perhaps regionalized, trends such as inclusion of e.g. aesthetic factors or cultural characteristics in the economic appraisal. On the other hand, a too high reliance on site-specific assessments could harm the idea of NBS as effective and competitive alternatives for climate adaptation, as they could come to be seen as extremely specific strategies creating very locally-bound (and complex to quantify) benefits. A new balance between local characteristics and more regional trends would allow us to reach, if not a seamlessly transferable quantification method, at least a common starting point for assessing NBS non-market benefits that could contribute to the uptake and upscaling of NBS.

3.3. Appraising limitations of SP methods

Despite the advantages offered by the SP approach in creating a replicable assessment of non-tangible benefits, limitations need to be addressed when considering the further application of this method. In the literature, a number of criticisms have been mentioned regarding SP methods. Probably one of the most cited is the possibility to run into hypothetical bias, due to the fact that the respondents' bids on an imaginary scenario can lead to unreliable estimates (e.g. due to free-riding, pressure to give the "correct answer", not fully understanding the scenario, etc.) (Schläpfer et al., 2004). However, it has been shown that hypothetical bias can be addressed through the comparison with results from other methods; for example, revealed preference approaches such as hedonic pricing or travel cost method (Bateman et al., 2006).

Further limitations include in-sample selection bias, non-response bias (Bateman et al., 2006), placing a heavy cognitive burden on the respondents (Ndebele and Forgie, 2017), and the risk of WTP responses to quantify the "moral satisfaction of contributing to public goods" rather than the actual economic values for these goods (Kahneman and Knetsch, 1992). Nevertheless, suggestions have been made to overcome all of these obstacles and can be applied to improve any adaptation or methodological development. Overall, when their limitations are properly addressed, SP approaches still remain the most reliable methods when endeavoring to value the non-market benefits of a specific good (Carson et al., 2014; Champ, 2017; Johnston et al., 2017).

4. Conclusions

This paper delivers an overview of how SP methods are currently used to assess intangible people benefits provided by NBS and NBS-like strategies, as well as how well they quantify the links between people and nature benefits. The study analyzes relevant non-market valuation studies from around the world and strives to highlight any biases or knowledge gaps of the current evaluation, and identify further research needs.

We show that there are still many challenges and unexploited opportunities in existing research concerning the integrated assessment of non-market human and nature benefits for nature-inspired strategies. The valuation of non-tangible benefits is still not so widespread, especially in projects explicitly labeled as NBS. Furthermore, most of the research is based on a case-to-case approach, and this study has struggled to find papers suggesting and opening paths for replication of their methodology. Steps are being taken, however, towards a more interconnected assessment of benefits (i.e. the majority of the studies include both people and nature benefits, and nature benefits are assessed in a way that takes into consideration "nature for nature" benefits). Nonetheless, for the most part, the current assessment approaches have applied pre-existing methods (e.g. valuation of ESS and recreation) and a predominantly anthropocentric perspective to benefit quantification. Overall, a shared holistic approach does not appear to emerge from the present literature.

Considering the emphasis placed on the need for a holistic assessment of NBS impacts, and the particularly relevant position that non-market benefits hold with regards to advocating for NBS during decision-making, there seems to be a mismatch between the actions that are needed for supporting NBS uptake and the methods available so far. Therefore, a new understanding and framing of the benefits of NBS and NBS-like strategies needs to come forward, advocating for more comprehensive and interconnected approaches. We argue that we need to actively ensure a paradigm shift occurs, away from the application of older methods towards a more holistic assessment, for the purpose of (i) not missing opportunities for the creation of multiple benefits across NBS domains, and (ii) assuring a thorough valuation of non-tangible benefits. Both these aspects will positively influence the cost-benefit analysis of both NBS and NBS-like

strategies, and increase their chance to increasingly be considered as feasible alternatives to "business-as-usual" climate adaptation strategies.

Thus, we suggest that further research could include the creation of a novel SP tool that should be: (i) easily tailorable to maximize its potential application across a wide variety of NBS, (ii) focused on people and nature non-market benefits, and their interconnections, and, where possible (iii) designed to ensure its potential for replicability and upscaling.

CRediT authorship contribution statement

Martina Viti: Writing - Original Draft, Investigation, Methodology, Data Curation, Visualization. **Roland Löwe**: Conceptualization, Writing - Review & Editing, Methodology. **Hjalte J.D. Sørup**: Writing - Review & Editing, Methodology. **Marzenna Rasmussen**: Writing - Review & Editing, Validation. **Karsten Arnbjerg-Nielsen**: Supervision, Writing - Review & Editing, Project Management, Funding acquisition. **Ursula S. McKnight**: Conceptualization, Supervision, Writing - Review & Editing, Validation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2022.156636.

References

Alves, A., Gersonius, B., Kapelan, Z., Vojinovic, Z., Sanchez, A., 2019. Assessing the co-benefits of green-blue-grey infrastructure for sustainable urban flood risk management. J. Environ. Manag. 239 (February), 244–254. https://doi.org/10.1016/j.jenvman.2019.03.036.

Alves, A., Vojinovic, Z., Kapelan, Z., Sanchez, A., Gersonius, B., 2020. Exploring trade-offs among the multiple benefits of green-blue-grey infrastructure for urban flood mitigation. Sci. Total Environ. 703, 134980. https://doi.org/10.1016/j.scitotenv.2019.134980.

Ando, A.W., Cadavid, C.L., Netusil, N.R., Parthum, B., 2020. Willingness-to-volunteer and stability of preferences between cities: estimating the benefits of stormwater management. J. Environ. Econ. Manag. 99, 102274. https://doi.org/10.1016/j.jeem.2019.102274.

Arrow, K., Solow, R., Portney, P.R., Leamer, E.E., Radner, R., Schuman, H., 1993. Report of the NOAA Panel on Contingent Valuation.

Balderas Torres, A., MacMillan, D.C., Skutsch, M., Lovett, J.C., 2015. 'Yes-in-my-backyard': spatial differences in the valuation of forest services and local co-benefits for carbon markets in México. Ecol. Econ. 109, 130–141. https://doi.org/10.1016/j.ecolecon.2014.11.008.

Bateman, Ian J., Day, B.H., Georgiou, S., Lake, I., 2006. The aggregation of environmental benefit values: welfare measures, distance decay and total WTP. Ecol. Econ. 60 (2), 450–460. https://doi.org/10.1016/j.ecolecon.2006.04.003.

Bateman, I.J., Brouwer, R., Ferrini, S., Schaafsma, M., Barton, D.N., Dubgaard, A., Hasler, B., Hime, S., Liekens, I., Navrud, S., De Nocker, L., Ščeponavičiūtė, R., Semėnienė, D., 2011. Making benefit transfers work: deriving and testing principles for value transfers for similar and dissimilar sites using a case study of the non-market benefits of water quality improvements across Europe. Environ. Resour. Econ. 50 (3), 365–387. https://doi.org/10.1007/s10640-011-9476-8.

Bayulken, B., Huisingh, D., Fisher, P.M.J., 2021. How are nature based solutions helping in the greening of cities in the context of crises such as climate change and pandemics? A comprehensive review. J. Clean. Prod. 288, 125569. https://doi.org/10.1016/j.jclepro.2020.125569.

Bockarjova, M., Botzen, W.J.W., Koetse, M.J., 2020. Economic valuation of green and blue nature in cities: a meta-analysis. Ecological Economics 169 (September 2019), 106480. https://doi.org/10.1016/j.ecolecon.2019.106480.

Carson, R.T., Groves, T., List, J.A., 2014. Consequentiality: a theoretical and experimental exploration of a single binary choice. J. Assoc. Environ. Resour. Econ. 1 (1/2), 171–207. https://doi.org/10.1086/676450.

Castellanos, L.A., Versini, P., Bonin, O., 2020. A Text-mining Approach to Compare Impacts and Benefits of Nature-based Solutions in Europe, pp. 1–19.

Champ, P.A., 2017. Collecting Nonmarket Valuation Data, pp. 55–82 https://doi.org/10.1007/978-94-007-7104-8_3.

Choi, C., Berry, P., Smith, A., 2021. The climate benefits, co-benefits, and trade-offs of green infrastructure: a systematic literature review. J. Environ. Manag. 291 (April), 112583. https://doi.org/10.1016/j.jenvman.2021.112583.

Cohen-Shacham, E., Walters, G., Janzen, C., Maginnis, S., 2016. Nature-based solutions to address global societal challenges. In: Cohen-Shacham, E., Walters, G., Janzen, C., Maginnis, S. (Eds.), Nature-based Solutions to Address Global Societal Challenges. IUCN International Union for Conservation of Nature https://doi.org/10.2305/IUCN.CH.2016.13.en.

Collins, R., Schaafsma, M., Hudson, M.D., 2017. The value of green walls to urban biodiversity. Land Use Policy 64, 114–123. https://doi.org/10.1016/j.landusepol.2017.02.025.

De Valck, J., Vlaeminck, P., Broekx, S., Liekens, I., Aertsens, J., Chen, W., Vranken, L., 2014. Benefits of clearing forest plantations to restore nature? Evidence from a discrete choice experiment in Flanders, Belgium. Landsc. Urban Plan. 125, 65–75. https://doi.org/10.1016/j.landurbplan.2014.02.006.

Derkzen, M.L., van Teeffelen, A.J.A., Verburg, P.H., 2017. Green infrastructure for urban climate adaptation: how do residents' views on climate impacts and green infrastructure shape adaptation preferences? Landsc. Urban Plan. 157, 106–130. https://doi.org/10.1016/j.landurbplan.2016.05.027.

Díaz, S., Pascual, U., Stenseke, M., Martín-López, B., Watson, R.T., Molnár, Z., Hill, R., Chan, K.M.A., Baste, I.A., Brauman, K.A., Polasky, S., Church, A., Lonsdale, M., Larigauderie, A., Leadley, P.W., van Oudenhoven, A.P.E., van der Plaat, F., Schröter, M., Lavorel, S., Shirayama, Y., 2018. Assessing nature's contributions to people. Science 359 (6373), 270–272. https://doi.org/10.1126/science.aap8826.

Din Dar, M.U., Shah, A.I., Bhat, S.A., Kumar, R., Huisingh, D., Kaur, R., 2021. Blue green infrastructure as a tool for sustainable urban development. J. Clean. Prod. 318 (June), 128474. https://doi.org/10.1016/j.jclepro.2021.128474.

Doherty, E., Murphy, G., Hynes, S., Buckley, C., 2014. Valuing ecosystem services across water bodies: results from a discrete choice experiment. Ecosyst. Serv. 7, 89–97. https://doi.org/10.1016/j.ecoser.2013.09.003.

Dumitru, A., Frantzeskaki, N., Collier, M., 2020. Identifying principles for the design of robust impact evaluation frameworks for nature-based solutions in cities. Environmental Science & Policy 112 (April 2019), 107–116. https://doi.org/10.1016/j.envsci.2020.05.024.

Dushkova, D., Haase, D., 2020. Not simply green: nature-based solutions as a concept and practical approach for sustainability studies and planning agendas in cities. Land 9 (1), 19. https://doi.org/10.3390/land9010019.

EEA, 2015. Natural Capital and Ecosystem Services.

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".

European Commission, 2021. Evaluating the Impact of Nature-based Solutions: A Summary for Policy Makers. https://doi.org/10.2777/2219.

Faccioli, M., Riera Font, A., Torres Figuerola, C.M., 2015. Valuing the recreational benefits of wetland adaptation to climate change: a trade-off between species' abundance and diversity. Environ. Manag. 55 (3), 550–563. https://doi.org/10.1007/s00267-014-0407-7.

Fletcher, T.D., Shuster, W., Hunt, W.F., Ashley, R., Butler, D., Arthur, S., Trowsdale, S., Barraud, S., Semadeni-Davies, A., Bertrand-Krajewski, J.-L., Mikkelsen, P.S., Rivard, G., Uhl, M., Dagenais, D., Viklander, M., 2015. SUDS, LID, BMPs, WSUD and more – the evolution and application of terminology surrounding urban drainage. Urban Water J. 12 (7), 525–542. https://doi.org/10.1080/1573062X.2014.916314.

Gelcich, S., Amar, F., Valdebenito, A., Castilla, J.C., Fernandez, M., Godoy, C., Biggs, D., 2013. Financing marine protected areas through visitor fees: insights from tourists willingness to pay in Chile. Ambio 42 (8), 975–984. https://doi.org/10.1007/s13280-013-0453-z.

Hagedoorn, L.C., Koetse, M.J., van Beukering, P.J.H., Brander, L.M., 2021. Reducing the finance gap for nature-based solutions with time contributions. Ecosyst. Serv. 52 (March), 101371. https://doi.org/10.1016/j.ecoser.2021.101371.

Hanson, H.I., Wickenberg, B., Alkan Olsson, J., 2020. Working on the boundaries—how do science use and interpret the nature-based solution concept? Land Use Policy 90 (October 2019), 104302. https://doi.org/10.1016/j.landusepol.2019.104302.

Hynes, S., Chen, W., Vondolia, K., Armstrong, C., O'Connor, E., 2021. Valuing the ecosystem service benefits from kelp forest restoration: A choice experiment from Norway. Ecological Economics 179 (September 2020), 106833. https://doi.org/10.1016/j.ecolecon.2020.106833.

IUCN, 2012. The IUCN Programme 2013 – 16. March 2012, pp. 184–210.

IUCN, 2020. IUCN Global Standard for Nature-based Solutions: a user-friendly framework for the verification, design and scaling up of NbS: first edition. IUCN Global Standard for Nature-based Solutions: A User-friendly Framework for the Verification, Design and Scaling up of NbS: First Edition. IUCN, International Union for Conservation of Nature https://doi.org/10.2305/IUCN.CH.2020.08.en.

Jia, H., Wang, Z., Zhen, X., Clar, M., Yu, S.L., 2017. China's sponge city construction: a discussion on technical approaches. Front. Environ. Sci. Eng. 11 (4), 18. https://doi.org/10.1007/s11783-017-0984-9.

Johnston, R.J., Boyle, K.J., Adamowicz, W.(Vic), Bennett, J., Brouwer, R., Cameron, T.A., Hanemann, W.M., Hanley, N., Ryan, M., Scarpa, R., Tourangeau, R., Vossler, C.A., 2017. Contemporary guidance for stated preference studies. J. Assoc. Environ. Resour. Econ. 4 (2), 319–405. https://doi.org/10.1086/691697.

Kahneman, D., Knetsch, J.L., 1992. Valuing public goods: the purchase of moral satisfaction. J. Environ. Econ. Manag. 22 (1), 57–70. https://doi.org/10.1016/0095-0696(92)90019-S.

Karanikola, P., Panagopoulos, T., Tampakis, S., 2017. Weekend visitors' views and perceptions at an urban national forest park of Cyprus during summertime. J. Outdoor Recreat. Tour. 17 (December 2015), 112–121. https://doi.org/10.1016/j.jort.2016.10.002.

Koetse, M., Brouwer, R., van Beukering, P.J.H., 2015. Economic valuation methods for ecosystem services. Ecosystem Services: From Concepts to Practice, pp. 108–131 https://doi.org/10.1017/CBO9781107477612.010.

Langergraber, G., Castellar, J.A.C., Pucher, B., Baganz, G.F.M., Milosevic, D., Andreucci, M.-B., Kearney, K., Pineda-Martos, R., Atanasova, N., 2021. A framework for addressing circularity challenges in cities with nature-based solutions. Water 13 (17), 2355. https://doi.org/10.3390/w13172355.

Lemaire, G., Carnohan, S., Grand, S., Mazel, V., Bjerg, P., McKnight, U., 2021. Data-driven system dynamics model for simulating water quantity and quality in peri-urban streams. Water 13 (21), 3002. https://doi.org/10.3390/w13213002.

Liu, W.-Y., Lin, Y.-Y., Chen, H.-S., Hsieh, C.-M., 2019. Assessing the amenity value of Forest ecosystem services: perspectives from the use of sustainable green spaces. Sustainability 11 (16), 4500. https://doi.org/10.3390/su11164500.

López-Mosquera, N., Sánchez, M., 2011. Emotional and satisfaction benefits to visitors as explanatory factors in the monetary valuation of environmental goods. An application to periurban green spaces. Land Use Policy 28 (1), 151–166. https://doi.org/10.1016/j.landusepol.2010.05.008.

Mant, J., Holman, I., Janes, V., Arthur, S., Haynes, H., Allen, D., Fenner, D., Hoang, L., Morgan, M., 2013. Delivering and Evaluating Multiple Flood Risk Benefits in Blue-Green Cities Key Project Outputs February.

Mäntymaa, E., Ovaskainen, V., Juutinen, A., Tyrväinen, L., 2018. Integrating nature-based tourism and forestry in private lands under heterogeneous visitor preferences for forest attributes. J. Environ. Plan. Manag. 61 (4), 724–746. https://doi.org/10.1080/09640568.2017.1333408.

Mejía, C.V., Brandt, S., 2017. Utilizing environmental information and pricing strategies to reduce externalities of tourism: the case of invasive species in the Galapagos. J. Sustain. Tour. 25 (6), 763–778. https://doi.org/10.1080/09669582.2016.1247847.

Mishra, P.P., 2017. The benefits of improving urban lakes in mega cities: a revealed and stated preference approach applied to the Hussain Sagar in Hyderabad, India. Environ. Dev. Econ. 22 (4), 447–469. https://doi.org/10.1017/S1355770X17000183.

Ndebele, T., Forgie, V., 2017. Estimating the economic benefits of a wetland restoration programme in New Zealand: a contingent valuation approach. Econ. Anal. Policy 55, 75–89. https://doi.org/10.1016/j.eap.2017.05.002.

Nielsen, A.B., Olsen, S.B., Lundhede, T., 2007. An economic valuation of the recreational benefits associated with nature-based forest management practices. Landsc. Urban Plan. 80 (1–2), 63–71. https://doi.org/10.1016/j.landurbplan.2006.06.003.

Norgaard, R.B., 2010. Ecosystem services: from eye-opening metaphor to complexity blinder. Ecol. Econ. 69 (6), 1219–1227. https://doi.org/10.1016/j.ecolecon.2009.11.009.

O'Donnell, E.C., Woodhouse, R., Thorne, C.R., 2018. Evaluating the multiple benefits of a sustainable drainage scheme in Newcastle, UK. Proc. Inst. Civ. Eng. Water Manage. 171 (4), 191–202. https://doi.org/10.1680/jwama.16.00103.

Pagano, A., Pluchinotta, I., Pengal, P., Cokan, B., Giordano, R., 2019. Engaging stakeholders in the assessment of NBS effectiveness in flood risk reduction: a participatory system dynamics model for benefits and co-benefits evaluation. Sci. Total Environ. 690, 543–555. https://doi.org/10.1016/j.scitotenv.2019.07.059.

Pérez-Urrestarazu, L., Blasco-Romero, A., Fernández-Cañero, R., 2017. Media and social impact valuation of a living wall: the case study of the Sagrado Corazon hospital in Seville (Spain). Urban For. Urban Green. 24, 141–148. https://doi.org/10.1016/j.ufug.2017.04.002 (November 2016).

Perrone, A., Inam, A., Albano, R., Adamowski, J., Sole, A., 2020. A participatory system dynamics modeling approach to facilitate collaborative flood risk management: a case study in the Bradano River (Italy). Journal of Hydrology 580 (November 2019), 124354. https://doi.org/10.1016/j.jhydrol.2019.124354.

Petcharat, A., Lee, Y., Chang, J.B., 2020. Choice experiments for estimating the non-market value of ecosystem services in the Bang Kachao Green Area, Thailand. Sustainability 12 (18), 7637. https://doi.org/10.3390/su12187637.

Pineda-Pinto, M., Frantzeskaki, N., Nygaard, C.A., 2021. The potential of nature-based solutions to deliver ecologically just cities: lessons for research and urban planning from a systematic literature review. Ambio https://doi.org/10.1007/s13280-021-01553-7.

Qiu, S., Yin, H., Deng, J., Li, M., 2020. Cost-effectiveness analysis of green-gray stormwater control measures for non-point source pollution. Int. J. Environ. Res. Public Health 17 (3), 998. https://doi.org/10.3390/ijerph17030998.

Ramajo-Hernández, J., del Saz-Salazar, S., 2012. Estimating the non-market benefits of water quality improvement for a case study in Spain: a contingent valuation approach. Environ. Sci. Pol. 22, 47–59. https://doi.org/10.1016/j.envsci.2012.05.006.

Raymond, C.M., Pam, B., Breil, M., Nita, M.R., Kabisch, N., de Bel, M., Enzi, V., Frantzeskaki, N., Geneletti, D., Cardinaletti, M., Lovinger, L., Basnou, C., Monteiro, A., Robrecht, H., Sgrigna, G., Munari, L., Calfapietra, C., 2017. An impact evaluation framework to support planning and evaluation of nature-based solutions projects. Report prepared by the EKLIPSE expert working group on nature-based solutions to promote climate resilience in urban areas. Horizon. 2020. https://doi.org/10.13140/RG.2.2.18682.08643.

Reynaud, A., Lanzanova, D., Liquete, C., Grizzetti, B., 2017. Going green? Ex-post valuation of a multipurpose water infrastructure in northern Italy. Ecosystem Services 27, 70–81. https://doi.org/10.1016/j.ecoser.2017.07.015.

Ruangpan, L., Vojinovic, Z., Di Sabatino, S., Leo, L.S., Capobianco, V., Oen, A.M.P., McClain, M.E., Lopez-Gunn, E., 2019. Nature-based solutions for hydro-meteorological risk reduction: a state-of-the-art review of the research area. Nat. Hazards Earth Syst. Sci. 20 (1), 243–270. https://doi.org/10.5194/nhess-20-243-2020.

Sabyrbekov, R., Dallimer, M., Navrud, S., 2020. Nature affinity and willingness to pay for urban green spaces in a developing country. Landsc. Urban Plan. 194, 103700. https://doi.org/10.1016/j.landurbplan.2019.103700 (December 2018).

Sato, M., Ushimaru, A., Minamoto, T., 2017. Effect of different personal histories on valuation for forest ecosystem services in urban areas: a case study of Mt. Rokko, Kobe, Japan. Urban For. Urban Green. 28 (October), 110–117. https://doi.org/10.1016/j.ufug.2017.09.016.

Schläpfer, F., Roschewitz, A., Hanley, N., 2004. Validation of stated preferences for public goods: a comparison of contingent valuation survey response and voting behaviour. Ecol. Econ. 51 (1–2), 1–16. https://doi.org/10.1016/j.ecolecon.2004.04.006.

Sharifi, A., Pathak, M., Joshi, C., He, B., 2021. A systematic review of the health co-benefits of urban climate change adaptation. Sustain. Cities Soc. 74 (June), 103190. https://doi.org/10.1016/j.scs.2021.103190.

Sirina, N., Hua, A., Gobert, J., 2017. What factors influence the value of an urban park within a medium-sized French conurbation? Urban For. Urban Green. 24 (August 2016), 45–54. https://doi.org/10.1016/j.ufug.2017.03.021.

Teotónio, I., Silva, C.M., Cruz, C.O., 2021. Economics of green roofs and green walls: a literature review. Sustain. Cities Soc. 69 (February), 102781. https://doi.org/10.1016/j.scs.2021.102781.

Thapa, S., Wang, L., Koirala, A., Shrestha, S., Bhattarai, S., Aye, W.N., 2020. Valuation of ecosystem services from an important wetland of Nepal: a study from Begnas watershed system. Wetlands 40 (5), 1071–1083. https://doi.org/10.1007/s13157-020-01303-7.

Toxopeus, H., Polzin, F., 2021. Reviewing financing barriers and strategies for urban nature-based solutions. J. Environ. Manag. 289 (August 2020), 112371. https://doi.org/10.1016/j.jenvman.2021.112371.

Tyrväinen, L., 2001. Economic valuation of urban forest benefits in Finland. J. Environ. Manag. 62 (1), 75–92. https://doi.org/10.1006/jema.2001.0421.

Tyrväinen, Liisa, Mäntymaa, E., Ovaskainen, V., 2014. Demand for enhanced forest amenities in private lands: the case of the Ruka-Kuusamo tourism area, Finland. Forest Policy Econ. 47, 4–13. https://doi.org/10.1016/j.forpol.2013.05.007.

Valasiuk, S., Czajkowski, M., Giergiczny, M., Żylicz, T., Veisten, K., Landa Mata, I., Halse, A.H., Elbakidze, M., Angelstam, P., 2018. Is forest landscape restoration socially desirable? A discrete choice experiment applied to the Scandinavian transboundary Fulufjället National Park Area. Restor. Ecol. 26 (2), 370–380. https://doi.org/10.1111/rec.12563.

Venkataramanan, V., Lopez, D., McCuskey, D.J., Kiefus, D., McDonald, R.I., Miller, W.M., Packman, A.I., Young, S.L., 2020. Knowledge, attitudes, intentions, and behavior related to green infrastructure for flood management: a systematic literature review. Sci. Total Environ. 720 (February), 137606. https://doi.org/10.1016/j.scitotenv.2020.137606.

Wihlborg, M., Sörensen, J., Alkan Olsson, J., 2019. Assessment of barriers and drivers for implementation of blue-green solutions in Swedish municipalities. J. Environ. Manag. 233 (July 2018), 706–718. https://doi.org/10.1016/j.jenvman.2018.12.018.

Wilker, J., Gruehn, D., 2017. The potential of contingent valuation for planning practice. The example of Dortmund westpark. Raumforsch. Raumordn. 75 (2), 171–185. https://doi.org/10.1007/s13147-016-0468-6.

World Bank, 2017. Implementing nature based flood protection. Implementing Nature Based Flood Protection. World Bank, Washington, DC https://doi.org/10.1596/28837.