TITLE: D5.1: REPORT ON COMPARATIVE ANALYSIS OF ECONOMIC VALUATION MODELS

CONEXUS
Urban nature connects us
Conectados por la naturaleza urbana
Conectados pela natureza urbana

Deliverable Number:	D5.1: Report on comparative analysis of economic valuation models
Version number	Version 1.3.
Lead partner	USFD (Beneficiary no. 1)
Due date	Month 30 (February 2023)
Deliverable Type (as per Grant Agreement)	R
Dissemination level	**CONFIDENTIAL**
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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 867564 tinyurl.com/conexus-project

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1. EXECUTIVE SUMMARY

1. Findings are presented from an investigation of nature-based solutions (NBS) research and case studies examining how projects address 'co-benefits', and particularly, their coverage of economic impacts.

2. A key issue for the evolution of NBS is how their impacts are evaluated (Dumitru & Wendling, 2021). Central to our study is whether NBS projects involve monetary valuation and if they addressed wide-ranging multiple benefits, or relatively few. This is now a central focus for NBS implementation (Whiteoak, 2020).

3. We report on research undertaken in partnership with seven cities in Latin America and Europe, namely Barcelona (Spain), Bogotá (Colombia), Buenos Aires (Argentina), Lisboa (Portugal), Santiago (Chile), São Paulo (Brazil) and Torino (Italy), through the Horizon 2020 Conexus project on urban NBS.

4. The research involved three main methods: (1) literature review addressing the theme of urban NBS and associated economic assessments; (2) focus groups pertaining to indicators of NBS impacts and relationships with monetary valuation; and (3) semi-structured interviews with representatives of city- and regional- government authorities in the Conexus cities.

5. Findings in relation to these methods are that:

   (i) a wide range of monetary valuation techniques have been applied to understand the economic impacts of urban NBS and NBS-like interventions within cities, but these studies tend to address just a handful of impact indicators which are mainly physical-environmental in their focus;

   (ii) developing a deeper understanding of (i) the socio-political context for NBS interventions within cities; (ii) the focus for those NBS and the most relevant impact indicators; and (iii) the most relevant economic valuation tools and methodologies can assist in advancing more meaningful discussions about the uptake of these approaches, and improve the prospects for success. Co-productive innovation methods involving transdisciplinary approaches and involving stakeholders from across the public, private, academic and third sectors can assist in developing this shared understanding; and

   (iii) whilst a wide range of economic valuation tools exist and can be applied to support the development of NBS programmes and project propositions, we find that evidence for their application is limited, and that key factors include overburdensome data demands, incommensurability with existing decision-making and accounting practices, and limited capacity – even within large capital cities.

6. Finally, it is concluded that the use of participatory impact assessment offers significant scope to improve the prospects for developing successful business cases for NBS incorporating monetary valuation, but only where those economic assessments are complemented by the use of other forms of data and assessments.

2. INTRODUCTION

2.1. The benefits of urban NBS and the finance gap facing cities to implement them

Urban NBS can provide multiple functions and benefits drawing on natural mechanisms, enabling cities to adapt to environmental changes and socio-economic challenges whilst also enhancing biodiversity (United Nation Environment Assembly 2022; Miyahara *et al.* 2022).

The *phrase* 'nature-based solutions' acts as a useful umbrella term for several valuable intervention types but the assembly of such broad sets of activities may also mask important differences between different NBS. Urban nature-based solutions offer real scope to bring nature back into areas where it is urgently needed, including to help solve social and economic problems in cities. Interventions such as sustainable drainage (Kozak *et al.* 2020), urban forestry (Barona *et al.* 2020) and daylighting of culverted rivers (Wild, Dempsey and Broadhead 2019) can deliver multiple benefits including reduced flood risk, water pollution, air quality and urban heat island impacts (Wild et al., 2020; EEA, 2021).

By addressing multiple policy priorities these interventions offer the potential to provide cost effective responses, cutting across diverse agendas (Wild et al., 2020). Paradoxically however, cities across the world face critical shortages in investment in NBS to respond to challenges such as urban climate adaptation ('urban adaptation finance gap'; Swann *et al*. 2021).

Marsters et al. (2021) call for the increased monetisation of NBS, suggesting that demonstrable performance metrics may support this process to increase private sector participation and unlock new and diverse funding streams. This repeats similar demands for better evidence quantifying the cost-benefit effectiveness of NBS and their impacts. In Europe, for instance, Whiteoak (2020) stresses the value of quantifying NBS cost-benefit effectiveness, whilst noting the "rarity" of shared data on the values side, as well as sometimes on the prices-side (Wild et al. 2017; 2019). Similarly, Vásquez and Dobbs (2020) highlight that the lack of economic valuation of NBS benefits remains a key barrier to development and implementation in Latin America and the Caribbean.

These two challenges - to find funding for NBS to deliver valuable benefits across multiple sectors and domains on the one hand, and the need for evidence on cost-effectiveness on the other - may well be related to one another, and this relationship provides the focus for this research, undertaken through the Horizon 2020 Conexus project. This paper builds on previous work seeking to strengthen NBS impact assessments, including research spanning multiple continents. This approach provides the chance to re-examine framings of NBS from around the world and to provide invaluable insights into opportunities and constraints to the uptake of NBS.

2.2. Are better data required to unlock urban NBS finance?

Traditionally, there has been little evidence of private sector investment in nature conservation and restoration (Dempsey and Suarez, 2016). Whilst the possibility exists that this lack of business finance may change rapidly due to international climate mitigation 'natural capital accounting' approaches (intended to secure funding from carbon credits, investment from the finance sector and so on), remain relatively new, and their effectiveness is largely untested. As a result, interest has grown rapidly in business cases (Mayor *et al.* 2021) around NBS, and their role in a 'nature-positive economy' (European Commission, 2022a).

In March 2022, the increasing interest in understanding the benefits of NBS, as well as the cost-effectiveness of interventions, was resulted in an updated definition of NBS agreed at the United Nations Environment Assembly (UNEA) Fifth Session (UNEA, 2022).

In Europe, this issue has come into sharp focus in the proposals for a nature restoration law, which suggested that: *"Overall, there is good evidence related to the costs and benefits of increasing urban green space… Due to the wide variation, however, in many aspects of the studies, such as the climate, locations and type of urban space, and the often limited parameters being investigated (pollution, energy, water runoff, health and well-being, climate mitigation etc) it is not possible to monetize some of these benefits in a generalized manner. Indeed, the high number of multiple co-benefits provided by using NBS to urban challenges tends to mean often the full benefits of urban green space and tree cover are underestimated. So, while it has not been possible to undertake a traditional cost/benefit analysis, as can be done on single issues, evidence points to the clear net positive values of halting the loss of, and then restoring green urban spaces." (EC 2022b, p.94).*

Ultimately, most NBS economic valuations share some form of analysis of their benefits, utilities or impacts, as the basis of understanding their cost-effectiveness. This may entail comparison with other (conventional, grey) infrastructures or responses. Therefore, the ways in which the various benefits of NBS are framed, synthesised and integrated becomes centrally important in how their economic values are understood.

The demonstrable benefits of NBS and the supporting data encompass the so-called 'business case' for return on investment. It is important to distinguish that the investor in a business case may be from any sector of a society (including the public sector), whereas the term business model (George and Bock 2011) refers specifically to organisational structures put in place to realise commercial opportunities, i.e. specifically in the private sector. NBS often produce a mix of benefits and services, some of which can be difficult to quantify in monetary terms, including public benefits that do not necessarily produce direct financial revenue streams (Wild, Henneberry & Gill 2017).

The use of typical market mechanisms such as private development schemes to deliver green infrastructure is restricted, because the goods arising from such investments have a high degree of non-excludability and non-rivalry (Wilker & Rusche 2014).

2.3. The importance of urban NBS valuations and impact assessment frameworks

Improved, practicable guidance to bridge the gap between data on NBS performance and economic valuation will be vital to support robust proposals to access funding from development finance institutions. For instance, the UN Adaptation Fund, to which the EU alone is contributing $100m, will require stronger business case analysis, and more robust treatment of the logic chain for management interventions. Established examples include the Food & Agriculture Organisation's 'Bankable Business Plans' model and associated guidance (FAO, 2021).

As regards funding from the private sector, between 2010 and 2014, cities received less than 5% of global adaptation finance despite containing more than half of the world's population (GCA, 2019; Richmond et al., 2021). The reality is that the vast majority of investment in ecosystems restoration using NBS continues to 'land' in rural areas, as evident in the Finance Earth Market

Review (2021). Notable exceptions often involve water treatment or management, often at the catchment scale (and so encompassing peri-urban and rural areas).

Urban adaptation finance includes only activities that address urban climate risk which directly affects the city and urban communities and/or occurs within the city boundary (Climate Policy Initiative 2020), with key challenges to mobilising finance including: (1) Incongruity with development finance institutions' mandates; (2) Low diversity of revenue streams lacking use of lucrative income, sales, and fuel taxes; (3) Lack jurisdictional control at relevant scales; (4) Low creditworthiness; (5) Poor policy, institutional and market environments; (6) High cost of projects and unknown value added; (7) Lack of technical capacity; and (8) Limitations of private insurance.

Three of these challenges are particularly relevant here, namely the added value and cost effectiveness, technical capacity and weak (governance) 'environments'. Additionally, a lack of region-specific information and methods may result in different and sometimes erroneous outcomes (Dobbs et al. 2019).

These challenges may be interwoven, and can stem from poor assessments of impacts, either in terms of systemic flaws (e.g. double counting; incommensurability of data) or indicators that lack specificity. Such problems can undermine the business case for NBS implementation by cities (i.e. municipal and regional government authorities). Furthermore, innovative accounting approaches often employed in NBS research projects may sit far from cities' socio-political realities, their extant calculative practices, and their norms in terms of economic planning and decision-making processes. The result may be a mismatch between policy-relevant evidence, and policy decisions themselves.

The intention of this study was therefore to seek to come closer to the reality as regards the application of monetary valuation methods in developing urban NBS programmes and projects. In particular, the project sought to draw on a wider set of cases and global contexts than has been achievable before, through the opportunity provided by the Horizon 2020 funding for international cooperation.

Key questions were as follows:

1. What knowledge exists about the benefits and costs of urban NBS in Latin American and European cities, how have monetary valuation methods been applied to understand the economic impacts of NBS, and what evidence is there of uptake of these methods in the studied cities?

2. How can NBS valuation methods be developed that are both sensitive to, and challenge, established institutionalised approaches to valuation, finance and governance? What is the role transdisciplinary and co-productive research in this?

3. How do economic valuations of urban NBS relate to the other frameworks and systems in place to understand their wider impacts in response to societal challenges?

3. METHODS

3.1. Reviewing the contemporary literature to establish the relevance of monetary valuation methods to urban NBS and the assessment of their impacts

The research reported here included literature reviews, workshop focus groups and semi-structured interviews aiming to understand the relationships between NBS impacts assessment, associated economic valuations and whether and how such methods are applied in cities. Central to our study is whether NBS projects involve monetary valuation and if they addressed wide-ranging multiple benefits, or relatively few. Since the focus of this research is on *urban* NBS, the research focussed on NBS *within cities* themselves, and in Latin America and Europe in particular.

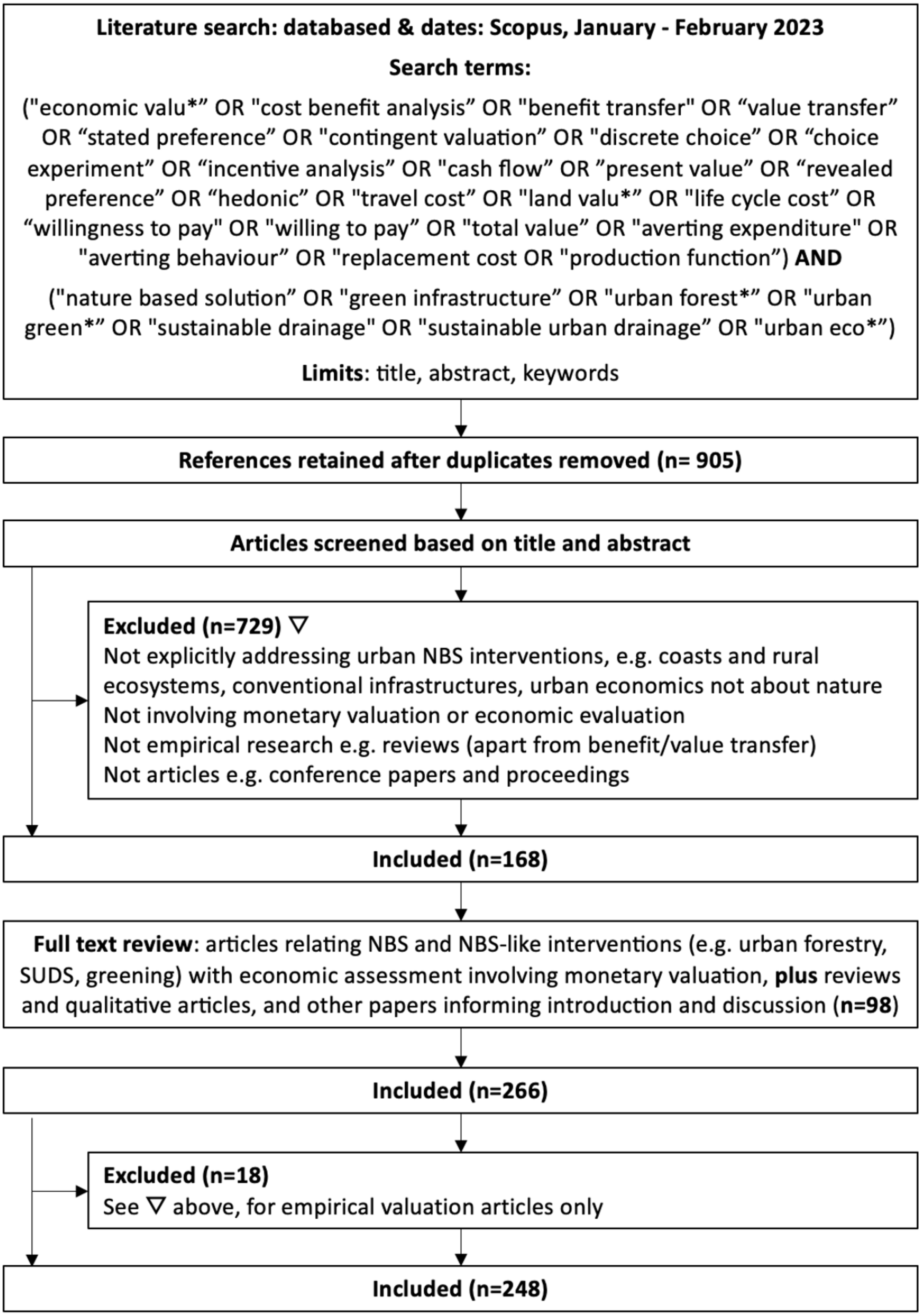
To inform the drafting of this manuscript and to feed into subsequent Conexus project tasks, a literature review was carried out between December 2022 and February 2023. Searches were undertaken using Scopus, and limited to the period from 2017 to present. Search terms for NBS and NBS-like interventions employed were deliberately kept broad to enhance coverage across a range of different research fields and global contexts. These included urban forestry, green infrastructure, sustainable drainage, NBS, urban greening and urban ecosystems / ecology. Phrases for economic valuation techniques (see Figure 1) were based on the search terms derived above ('inventory') along with other monetary valuation methods described in Ozdemiroglu & Hails (2016). In this instance, abstracts were drawn from the global databases, in contrast with the literature focusing on Latin American and European cities described in part one of the methods.

The diagram below sets out the methods employed in this review drawing on the PRISMA approach for reporting systematic reviews (Liberati et al., 2009; Moher et al., 2009). Abstracts, keywords and titles were screened for relevance and codified for the application of specified monetary valuation techniques, with the codification being undertaken by two researchers. Blind reviews of abstracts were used to reduce bias in the development, refinement and application of the codification system and the screening methodology. An iterative process of reviewing and comparing the coded contents was undertaken for each category (after Glaser, 1965).

Results of the literature review were stored and processed in Excel spreadsheets. Abstracts were twice screened once at the level of the different domains (NBS, urban forest etc), and again within a combined spreadsheet including results for all domains (conservatively, i.e. where in doubt abstracts were retained for further scrutiny). Each dataset was screened using the following criteria for exclusion: (a) does not address NBS interventions in the urban fabric, e.g. pertains to rural ecosystems, coastal ecosystems, conventional infrastructures or no NBS interventions were being tested; (b) does not involve monetary valuation; (c) does not entail empirical study e.g. reviews; (d) does not represent a peer reviewed published manuscript e.g. conference papers.

Where abstracts were ruled out, reasons for screening out were recorded to enable cross-comparison between results for searches across the different domains or by different researchers, and again, where in doubt, entries were retained for further scrutiny. Duplications were then removed prior to analysis of full manuscripts to code relevant content. The results were used in the introduction and discussion sections of this article and were passed to the Conexus cities' contacts for capacity-building purposes.

Figure 1. Flow diagram of record selection.



Notes: an asterisk notates the use of the * wildcard in Scopus.

3.2. Case studies review to establish inventories of reported NBS impacts & economic valuations

The starting point for this early phase in the research was to provide a framework for understanding different types of monetary assessments with an explicit emphasis on a broad range of climatic, geographical, ecological and socio-political contexts.

To ensure this work was of relevance to the H2020 Conexus cities, we reviewed abstracts of over 400 published cases selected by Amaya-Espinel et al. (2021), which drew on references relating to green infrastructure and urban forestry as well as NBS. This included works with a good representation of literature from Latin America as well as cities in Europe, which tended to be more heavily researched as regards the historical development of NBS policies and concepts. References collated through an EC-funded review (Wild et al., 2020) were also re-examined. This work was undertaken between September 2021 and April 2022.

From the cases database, abstracts were screened by two researchers to establish, in a bottom-up manner: (a) what kinds of societal challenges were addressed in the literature in terms of intended impacts and indicators; and (b) any applications of economic valuation methods. Indicators identified within abstracts, which addressed a wide range of social, technical, environmental, political and cultural aspects, were then categorised using the framework for understanding co-benefits provided by Dumitru & Wendling (2021) in the EC's NBS Impact Assessment Handbook. Each reference was recorded as a unique record in an MS Excel spreadsheet, with associated impact indicators being noted for the relevant study. Details of economic valuation methods applied were logged for each abstract (alongside other impact indicators). Categories and terms for this resulting inventory of valuation methods were discussed and agreed between the authors. Through this classification, we aimed to identify indicators used to evaluate co-benefits of NBS, so we could match the selected indicators with relevant papers describing valuation methods.

3.3. Focus groups with 6 Conexus cities: co-producing understanding of relationships between impact indicators and valuations

To jointly establish how economic valuations may be performed in different contexts and applying a range of impact indicators, a workshop was organised involving the H2020 Conexus cities and other partners. This workshop, held in person in São Paulo (Brazil) on 26th May 2022, involved representatives of local and regional government authorities from the cities of Barcelona (Spain), Bogotá (Colombia), Buenos Aires (Argentina), Santiago (Chile), São Paulo (Brazil) and Torino (Italy). Partners from Lisboa (Portugal) were invited but were unable to attend. These municipal and regional government partners are responsible for delivering NBS programmes and pilots in the H2020 Conexus cities.

Workshops were held as a series of six city-specific breakout groups, involving participants from the public sectors, NGOs, researchers, and representatives of SMEs. Prior to the meeting, project partners had established the most relevant indicators to assess impacts of their NBS programmes and projects across societal challenge areas (van der Jagt et al., 2022; 2023) using an action framework for the participatory assessment of NBS in cities. The purpose of the discussions was to seek to understand what is driving the need for economic data and other NBS performance data.

Based on these indicators selected by the cities, abstracts reporting economic valuations applied were filtered according to the most relevant topics and themes. These city-specific sets of abstracts were sent to the workshop participants in advance. Around 15-20 abstracts were sent to each city (group), drawn from the above dataset (after Amaya-Espinel et al., 2021 and Wild et al., 2020). Abstracts were translated into local languages using an automated service (DeepL Pro) and accompanied by a short introductory brief along with the workshop agenda. During the workshop, simplified explanations for each valuation technique were provided, again translated into local languages to assist participants. Workshop participants were asked in advance to go through the abstracts and to highlight any cases that were 'very relevant' or 'irrelevant' in preparation for the group discussions.

During the participatory workshop sessions, the pros and cons of different economic valuation methodologies were discussed, along with their relevance in terms of the indicators applied in different cities and reported in the literature. Breakout discussions were held in locally relevant languages except for Torino, the session for which was held in English. Sessions were convened by researcher facilitators. Breakout group participants identified notable studies using a unique reference number for each abstract and also noted why those cases were felt to be more or less relevant for their city and NBS projects. Facilitators captured key points of these discussions live, using flipchart paper. Individual participants were then asked to 'vote' for their most preferred methods, using sticky dots attached to the flipcharts, alongside the relevant source references.

Breakout group participants debated whether and how different monetary valuations were applied for different impacts, such as heat island mitigation, flood risk management, air pollution amelioration and so on. In order to generate an overview of the kinds of topics and impacts that are relevant across the Conexus cities, a poll was organised using Menti.com during a conference plenary session. This poll, conducted in such a way as to allow the 39 individual respondents' answers to be tracked cross different questions, covered participants': (1) personal names; (2) organisation; (3) Conexus city; (4) NBS pilot projects of relevance; (5) societal challenge areas (according to Dumitru & Wendling (2021); and (6) most pertinent indicators of NBS impacts.

The results of the focus group discussions were summed up during a conference plenary session, as well as being circulated to participants after the event. Based on these discussions, recommendations were made for a subset of monetary valuation techniques of relevance in each of the Conexus cities, for use in subsequent project tasks concerned with the actual implementation of economic assessments and business planning for NBS uptake.

During focus groups, participants were also asked to identify appropriate contact persons in each of the Conexus cities who might be interested in valuation techniques, e.g. economists or accountants working in the municipalities or government authorities (see below).

3.4. Semi-structured interviews to understanding how Conexus cities view monetary valuation of urban nature and NBS – including if and how economic assessments are applied

To complement information on current methods used in economic assessments of NBS, we conducted semi-structured interviews with contacts whose role it is to either perform monetary valuation of urban nature in each city, or to understand how such techniques may be applied to support decision-making. Interviews have been used in conservation science in order to understand stakeholders' knowledge, values, beliefs or decision-making processes (Young et al., 2018). The semi-structured method was selected to provide a flexible approach enabling in-depth analysis and placing the focus of research on the experience of participants (ibid).

Interviews had the aim to establish how the NBS projects formulate impacts and co-benefits, and to explore how economic assessments are applied (or not) in their decision-making process. Contacts were identified by Conexus project partners during and post workshop discussions. During the interviews, primary contacts were also asked to provide further contact details of other participants that would be relevant to interview about the topic in their institutions. This snowballing of contacts enabled the further identification of relevant stakeholders in each city.

We interviewed 12 participants with a different range of roles, working in regional to municipal scale, most of whom were directly involved in the decision-making processes or decision support. Semi-structured interviews, formulated by three of the authors, were undertaken between June 2022 and December 2022. In the first part of the interview, general questions were asked to understand participants' professional backgrounds and experience until the current job position. More specific questions covered their current roles, including the daily tasks they perform, with a view to understanding what skills and knowledge are applied to the role, and if/how these support the decision-making process in their city.

In the last section of the interview, the focus was on participants' opinions and knowledge about NBS, and the economic valuation of benefits. This last part had the focus to establish if/how those interviewed are involved in the economic valuation of new projects in their cities, in what instances an economic valuation is needed, and if possible, their understanding of methods involved in the process. Perspectives of the different valuation methods were discussed along with their relevance or otherwise in each city. From these discussions, we seek to understand what was driving the need for economic data and other NBS performance data. A list of guiding questions can be found in Annex 1

All interviews were transcribed in their original language and later translated to English using Deepl Pro Translate software (version 4.1). The selection of relevant information process was undertaken through examination of original versions of the transcripts. We highlighted relevant information that providing answers to our main questions, or important contextual information. Textual analysis was carried out in MS Word and data were organised using MS Excel spreadsheets. Thematic analyses were conducted using a hybrid approach; firstly deductive, to identify broader interview themes, and then inductive, to establish emerging sub-themes within those broader topics, and to explore theoretical perspectives concerning the observed evidence and narratives.

4. RESULTS

4.1. Literature on monetary valuation methods applied to the assessment of urban NBS impacts

For the literature review completed for the purposes of writing this manuscript (January-February 2023), over 900 abstracts were screened with 729 not meeting the selection criteria (Fig.1). A further 98 references including literature reviews and policy documents were also considered in drafting this report. A total of 248 full texts were reviewed, feeding into the introduction and discussion sections. Different valuation methods have been used to assess the multiple benefits delivered by NBS, and NBS-like interventions (green infrastructure, urban forestry, urban greening and so on). In using the phrases economic assessment, monetary valuation and economic valuation, this is intended to cover all methods used to calculate the value of market and non-market goods. It includes direct and indirect use values (market values) and also values relating to the satisfaction provided by the existence of a given good or service and potential benefits given to future generations (non-market values).

4.1a. Economic valuation, in its widest sense, of NBS

In general, the *economic valuation* of NBS and related urban greening interventions have been reported across a wide range of disciplines and domains, with numbers of publications growing year on year (Wild et al., 2020). The literature identifies specific cases of assessments relating to urban ecology and urban ecosystem services (Fruth et al., 2019, 2020; Islam et al. 2019; Johnson & Geisendorf, 2019; Johnson et al., 2021; Ma, Henneberry & Privitera, 2021; Mäntymaa et al., 2021., Martínez-Paz J.M. et al., 2021; Sinha et al., 2021; Suarez et al. 2021; Wang et al., 2022).

Several authors report on *economic valuations* referring explicitly to NBS (e.g. Derkzen et al. 2017; Wild et al., 2017; Okada et al. 2021; Sikorska et al. 2020; Masiero et al. 2022; Neumann & Hack, 2022) building on a longer heritage of valuations relating to green infrastructure (Derkzen et al., 2017; Collins et al., 2017; Hoover et al., 2020; Hsu & Chao, 2020; Almeida et al., 2021; Johnson et al., 2021; Lim & Xenarios, 2021, Masiero et al., 2022), urban greening (Botes & Zanni, 2021; Fruth et al. 2020; Rezwan et al., 2022; Tudiwer et al., 2019), urban forestry (Bertram & Larondelle, 2017; Riley et al., 2018) and sustainable drainage or SUDS (Johnson & Geisendorf, 2019; Vincent et al., 2017).

Often, economic valuation studies refer to several of these terms in relation to one another or use them interchangeably, (Derkzen et al., 2017; Riley et al., 2018; Fruth et al., 2019, 2020; Johnson & Geisendorf, 2019; Sikorska et al., 2020; Johnson et al., 2021; Lim & Xenarios, 2021; Masiero et al., 2022) which is not surprising and may not be problematic.

Economic valuations can relate to the smallest micro scale (e.g. green roofs and walls, Almeida et al., 2021) through to the bigger sites (e.g. large urban forest interventions, Bertram & Larondelle 2017) and to individual treatments such as street-level greening (Fruth et al., 2019, 2020) or combinations of various NBS elements (Wild et al., 2017) or the integration of NBS with other urban design interventions (e.g. Botes & Zanni, 2021).

Interestingly, relatively few studies focus on the economic valuation of biodiversity impacts (Collins et al. 2017, Riley et al. 2018, Ebenberger & Arnberger 2019, and Rezwan et al., 2022; see also Naumann in Wild et al., 2020) but explicit links with climate change and other urban challenges are relatively commonplace (e.g. flooding - Derkzen et al., 2017; urban water scarcity - Wang et al., 2022; urban heat island effect - Tudiwer et al., 2019, Sinha et al., 2021; energy and climate mitigation - Sikorska, 2020). Often the benefits cut across one another e.g. contributions of SUDS in mitigating urban heat (Johnson et al. 2021, 2021b).

Vincent et al. (2017) note that certain NBS investments are not accounted for as beneficial unless or until a broad range of ecosystem service benefits are taken into account. Okada et al. (2021) recommend that these values should represent collective ecosystem services (ES) and other intangible benefits. A related problem is that the economic value of green infrastructure is not adequately reflected in market prices and novel methods of economic valuation are needed to ascertain their value (Hsu & Chao, 2020). Croci et al. (2021) go further in their assertion that whilst the “literature on ES valuation has grown in recent years, its application to urban contexts is still limited”, whilst noting that this conclusion was “based on limited available literature”.

Monetary values do not necessarily reflect the social importance that individuals assign to ecosystem services (Suarez et al., 2021). In understanding the connections between urban nature and human health and wellbeing, more effective economic valuation of the net benefits of nature-based investment are needed along with comprehensive frameworks for valuing natural and non-market goods and services (Ma, Henneberry & Privitera, 2021). Some innovative and interesting approaches have thus been developed, including socio-cultural valuation (Derkzen et al. 2017), combinations of qualitative and quantitative methods (e.g. Neumann & Hack, 2022; Teotónio et al. 2022) and efforts to obtain in-depth knowledge of perceptions and beliefs to incorporate into valuations (Islam et al., 2019).

Before delving into the specific monetary valuation techniques that follow, it is worth stressing here some of the more unique aspects of retrofitting NBS into urban contexts.

First, the proximity of NBS interventions to large numbers of people and high concentrations of housing bring about particular dynamics and 'spikes' in ecosystem services that restoration schemes in urban areas can deliver as highlighted by Wild et al. (2019): urban landscapes have become "the everyday environment for the majority of the global population" (Haase et al., 2014). This also explains in part the attraction of hedonic studies relating house prices to NBS values (see separate section below). Second is the relationship between aging city infrastructures (Hoover et al., 2020), urban renewal (Hsu & Chao, 2020), the regeneration of brownfield sites (Masiero et al., 2022) and the role of NBS in inner-city abandoned and vacant lots (Riley et al. 2018). Third, whilst potential benefits of NBS retrofits include recreational, socio-cultural and tourism-related values (Mäntymaa et al., 2021; Lim & Xenarios, 2021), concerns about the potential for urban greening to contribute to gentrification must be addressed and monetary valuation studies can provide invaluable insights in this respect (Hunter et al. 2019, Bockarjova et al 2020a, 2020b; Basu & Nagendra, 2021; Donovan et al. 2021; Wu & Rowe, 2022; Sachs et al, 2023; Stroud et al, 2023).

4.1b. Cost-benefit analysis

Since most monetary valuations ultimately involve some form of *cost-benefit analysis* (CBA), it is not surprising that a significant proportion of the literature around economic assessment of NBS and NBS-like interventions (domains such as urban forestry and urban greening) refer to this category of economic assessment.

References in the literature on performed CBA relating *explicitly to NBS* in urban settings[1] are growing in number each year and cover a wide range of impacts and contexts, including NBS for: *air quality improvement* (Nemitz et al., 2020; Chen et al., 2023); *brownfield remediation* (O'Connor & Hou, 2020; Masiero et al., 2022); *energy and climate mitigation* (Sikorska et al., 2020; Ciasca et al., 2023); *recreation and aesthetics* (Teotónio et al., 2020; 2022); and *urban water management, water pollution control, drought and flood risk management* (Wild et al., 2017; Singh et al., 2019; Jerzy et al., 2020; Rizzo et al., 2021; Turkelboom et al., 2021; Rizzo et al., 2021; Neumann & Hack, 2022; Quaranta et al., 2022; Reu Junqueira et al., 2022; Ciasca et al., 2023; Stroud et al., 2023).

The literature on CBA in relation to *green infrastructure* (GI) is far more extensive, likely reflecting the longer historical use of this phrase. Frequently assessed benefits and impacts include: water resource provision (Brent et al., 2017; Boguniewicz-Zabłocka & Capodaglio, 2020; Godyń et al., 2020, 2022; Hagen et al., 2017); house prices and land values (Irwin et al., 2017; Wild et al., 2017; Iváncsics et al. 2019; Hoover et al. 2020). Hekrle (2022) notes that most for ecosystem services

[1] i.e. excluding rural and coastal NBS interventions, and qualitative reviews, see Methods.

analyses reported in the literature, *generally specified* NBS such as “green spaces” or “green infrastructure” prevail.

Very many CBA studies address water management related issues, including wastewater treatment, water quality improvement and nutrient removal (Brent et al., 2017; Hagen et al., 2017; Nordman et al., 2018; Yang & Chui, 2018; Wu et al., 2019; Xu & Zhang., 2019; Boguniewicz-Zabłocka & Capodaglio, 2020; Xing et al., 2021; Heidari et al., 2022; Yao et al., 2022); and managing stormwater to detain runoff and reduce flood risks (Mei et al., 2018; Nordman et al., 2018; Yang & Chui, 2018; Fu et al., 2019; Alves et al., 2019; Xu & Zhang, 2019; Li et al., 2020; Godyń et al., 2020, 2022; Azis & Zulkifli, 2021; Kvitsjøen et al., 2021; Hérivaux & Coent, 2021; Xing et al., 2021; Khan et al., 2022; Wilbers et al., 2022; Yao et al., 2022).

Several studies address the multiple benefits of GI, e.g. recreation, aesthetics and wellbeing (Matos Silva et al. 2019; Rizzo et al. 2021; Shah et al., 2022), or reductions in stormwater runoff, air pollution and urban heat impacts (Brent et al., 2017; Wild et al. 2017; Nordman et al., 2018; Alves et al. 2019; Iváncsics et al., 2019; Hérivaux & Coent, 2021; Johnson et al., 2021), or combinations of all of the above impacts by integrating CBA with multicriteria analysis (Teotónio et a. 2022). Less commonly analysed impacts in CBA studies of GI include urban agriculture (Kyoi, 2021); urban renewal (Hsu & Chao, 2020); air quality improvement (Nemitz et al., 2020); sound aesthetics (Almeida et al., 2021); socio-cultural and tourism-related values (Lim & Xenarios, 2021); ecological connectivity (Liu et al., 2020); or energy supply (Sikorska et al. 2020). As can be seen above, many CBA studies address multiple benefits of water management using GI. Fewer studies investigate trade-offs between services and disservices (Shah et al. 2022).

Urban greening, a term often used interchangeably with GI, has a slightly different literature base as regards CBA, perhaps reflecting a stronger connotation of urban GI intervention and retrofit within cities. Impacts assessed include biodiversity (Gwak et al., 2017; Shah et al. 2022), heat mitigation and energy savings (He et al., 2021; Johnson & Geisendorf, 2021; Claron et al., 2022), recreation, health and wellbeing outcomes (Kim et al., 2018; Shah et al. 2022; Claron et al., 2022), air quality improvements (Nemitz et al., 2020), and again a range of water management impacts including runoff reduction, pollution control and flood risk management (Wild et al., 2017; Li et al., 2020; Johnson & Geisendorf, 2021; Quaranta et al. 2022; Claron et al., 2022). Once more, some CBA studies investigate multiple benefits (e.g. Gwak et al., 2017; Iváncsics et al. 2019; Claron et al., 2022) and trade-offs (Shah et al. 2022).

Several CBA studies refer specifically to *urban ecosystem services or ecological restoration* in cities associated with intervention programmes and projects. These include monetary valuations urban agriculture in community gardens in terms of social impacts (Dubová & Macháč, 2019) and of biodiversity benefits (Wan et al., 2018), with the latter also being assessed for green roofs (Gwak et al., 2017). Removing or preventing soil sealing is the subject of CBAs addressing urban heat, wellbeing and stormwater runoff impacts (Johnson et al. 2021; Claron et al. 2022), also addressed by studies of sustainable drainage (Johnson & Geisendorf, 2019; Wang et al. 2022). Brownfield greening CBAs have also assessed recreation, cooling, flood risks and carbon sequestration (Zhong et al. 2020).

Whilst many of the above studies entail CBA of water management, several studies refer specifically to *sustainable drainage or SUDS*. CBAs have addressed stormwater runoff (Zubelzu, 2019; dos Santos et al. 2021) also in combination with environmental costs in terms of life-cycle impacts (Abdeljaber et al. 2022) and pollution control (Cooper et al. 2019), as well as the above impacts in combination (Fraga et al., 2022); several assessments demonstrate that interventions become more cost-effective when several of these co-benefits and intangibles are incorporated (Vincent et al. 2017; Alves et al. 2019; Johnson & Geisendorf, 2019; Oladunjoye et al. 2022).

4.1c. Benefit transfer and value transfer

Benefit transfer or value transfer involves the transfer of original ecosystem service value estimates, from an existing study site or multiple study sites, to an unstudied site with similar characteristics (Richardson et al., 2015); it has been used in monetary valuation of ecosystem services because the primary research providing these values has not kept pace with the increase in demand for this information (Bateman et al., 2011). Use of benefit transfer has been fundamental to the development of natural capital accounting approaches (e.g. see Defra, 2010). These techniques have prominence in economic policy analysis in that policy analysts can rarely employ original studies, but there are significant trade-offs between simplicity and accuracy; hence application and uptake of associated valuations should be subject to the use of good practice guidance (OECD, 2018).

Benefit transfer methods have been applied in the valuation of services derived from: *urban stormwater management* (Brent et al., 2017 – Australia; Nordman et al., 2018 – USA; Rizzo et al., 2021 – Italy; Ossa-Moreno et al., 2017 - UK); *urban green spaces* (Diluiso et al., 2021 – Europe; Bockarjova et al., 2020 – the Netherlands), *urban forests* (Tapsuwan et al., 2021- Australia; Bherwani et al., 2022 – India; Zhao et al., 2021 – China); *combinations of urban blue and green infrastructures* (e.g. Skrydstrup et al., 2022 - Europe: SUDS, parks, nature areas and rivers); and *urban ecosystem services* more generally (e.g., Zhao et al., 2018 - China; Bockarjova et al., 2020 - Europe).

Yi et al. (2017) reiterate that the ability to confidently use value coefficients when applying benefit transfer methods to estimate ESVs demands rigorous assessments of their broad applicability. Morgan & Fenner (2019) critique benefit transfer in that it does not systematically incorporate the spatial nature of the benefits and suggest ways to enable direct comparison of the relative magnitude of benefits for a given location.

4.1d. Stated preference

Stated preference tests are highly flexible and have been widely applied in economic valuations such as those assessing willingness to pay (Barton, undated). They have been applied in valuations covering NBS (e.g. Hagedoorn et al. 2021; Hekrle M., 2022), urban forestry (e.g. Davies et al., 2023), GI (e.g. Teotónio et al., 2020; Tanaka et al., 2022), SUDS (e.g. Jarvie et al., 2017), and urban greening interventions to deliver urban ecosystem services (e.g. Vanstockem et al., 2018; Łaszkiewicz et al. 2019). Stated preference tests often form the basis of willingness to pay studies estimating of direct, indirect or non-use values. Applications of two common stated preference valuation techniques, *discrete choice experiments and contingent valuation* as reported in the literature are set out below.

Contingent valuation method (CVM)

In relation to *urban tree planting and urban forestry,* In Atlanta, USA Tran et al. (2017) used CVM to establish households' willingness to increase urban forests to mitigate against climate change impacts and related issues, such as sequestering carbon, reducing air pollution, and decreasing the heat island effect. They found the WTP amount was significantly related with the residents' income, media and relative coverage of tree canopy. In the Democratic Republic of Congo (DRC), Balasha et al. (2022) applied CVM finding that students' awareness and exposure to media publicity affected the prices they were willing to pay (WTP) for trees to improve the attractiveness, sustainability and quality of educational environments.

With a particular focus on *urban regeneration projects*, using CVM, Idczak et al. (2019) established that projects integrating urban ecosystem restoration outperformed projects with little or no urban ecosystem services in terms of higher values of the economic performance indicators and their stronger contribution to urban sustainable development.

As regards *water quality and river restoration*, Islam et al. (2019) and Yaacovi et al. (2021) have applied CVM in Dhaka, Bangladesh and Ein-Zahav in northern Israel, to establish WTP levels for improved water quality (along with improved flow management, cultural services and riverbank maintenance in the latter case), finding that respondents' mean incomes but also perceived extant water quality had a significant impact on decisions.

Green roofs were studied in Beijing, China by Zhang et al. (2019) using CVM. As well as the 'conventional determinants' described above (respondents' income and education), they found that social norms, attitudes and perceived behavioural control significantly affected willingness to pay for green roofs to mitigating heat island effects.

In relation to *urban green space enhancement*, and *access to nature*, CVM has been applied widely and has also been combined with hedonic pricing studies and travel cost methods. In Greece, Kalfas et al. (2022) found that income and knowledge of environmental issues (global and local) as well as the benefits of green spaces are key factors that drive residents to place a higher value on urban greenspaces. At Oulu in Finland, Mäntymaa (2021) also found that income was a factor – but individuals with low incomes valued restoration in an urban park more than wealthier individuals – people perceived benefits for their wellbeing, and ecosystem restoration tended to increase the number of visits to and value of the park.

Also on the valuation of access to nature in urban green spaces, Sabyrbekov et al (2020) used CVM alongside application of a nature relatedness scale in Bishkek, Kyrgyzstan. They found that high attachment to nature does not necessarily lead to support for improved provision since WTP is constrained by household income, education and size; they conclude that valuations are improved by combining monetary and non-monetary approaches. Finally, in Murcia Spain, Martínez-Paz et al. (2021) found that distances to project areas and substitute areas explain WTP; their CVM study recommends the targeting of interventions to areas with high accessibility and low number of substitutes, to maximise future benefits.

Benefits of *air purification* have also been researched using CVM. In Guangzhou, China Zhang et al. (2020) found that younger respondents who might have lower incomes would like to pay more for small urban GI interventions – green roof, green wall, and green corridor and their maintenance – as compared with elderly respondents. People were willing to pay most for air quality regulation services. However, in the Colombian Andean region Suarez et al. (2021) used CVM to identify mismatches between the monetary and social values of air purification - despite the high level of social importance that respondents assigned to air purification, this had no correlation with payment values. They stress the need to integrate social and monetary values into decision-making processes.

Regarding the multiple benefits of *SUDS and GI for water management,* Reynaud et al. (2017) used CVM in Gorla Maggiore, Italy, finding that people were willing to pay more for a restored blue-green 'neo-ecosystem' c.f. conventional. In Edinburgh, Scotland Jarvie et al. (2017) applied this method establishing that the multiple benefits of SUDS ponds as perceived by the public exceeded the capital and operational for three of five installations. Tanaka et al. (2022) found using CVM that citizens in Portland, Oregon were willing to pay more for enhanced SUDS that would lead to more private benefits (e.g., rain barrels, urban trees) whereas public installations e.g., bioswales, rain gardens would receive less support (and relative importance varied widely among respondents). Oladunjoye et al. (2022) also assessed WTP for SUDS retrofits as part of their CBA.

Wang et al. (2022) investigated residents' willingness to pay for *SUDS in industrial development contexts* in Auckland (water sensitive urban design). Middle income, pre-middle age, and 10+ year residence groups were associated with higher willingness to pay levels, with rain gardens, trees, and green roofs being most highly valued.

Derkzen et al. (2017) explored residents' values around *GI* interventions to address climate impacts through a socio-cultural valuation including CVM methods. They found that citizens had concerns about climate impacts, but did not necessarily acknowledge that GI may help tackle these issues. When residents were informed about the adaptation capacity benefits their preferences shifted towards effective GI measures, but this had no effect on people's willingness to pay, which was mostly related to income and ethnicity.

Finally, on the critically important topic of *NBS maintenance*, using CVM, Qiao & Randrup (2022) found that educational level and respondents' age affects willingness to pay for the maintenance of GI to manage stormwater onsite and reduce flooding, whereas knowledge of the concept of sponge cities did not influence the amount of payment.

Discrete choice experiments (DCE)

Discrete Choice Experiments (DCE) or simply *Choice Experiments* have been applied in a range of settings to understand the conditions, contexts and viability of NBS interventions.

As regards *water management*, this includes flood control structures, and stormwater management NBS such as *SUDS and blue-green infrastructure interventions.* Willingness to pay for *stormwater management NBS (SUDS)* interventions was evaluated using DCE by Brent et al. (2017) in their studies in Melbourne and Sydney, Australia. Highest levels of WTP were found for improvements in local stream health, exemptions in water restrictions, flash flooding prevention, and decreases in peak urban temperatures.

In Chicago and Portland USA, Ando et al. (2020) used DCE to estimate the benefits of SUDS (stormwater management NBS) in terms of stated willingness to pay or to volunteer time, finding that willingness to pay was largely stable across cities. Willingness to volunteer time was not correlated with wage rate; in other words, people appeared to gain positive utility from volunteering. Johnson & Geisendorf (2022) used DCE to understand preferences and willingness to pay for ecosystem services provided by SUDS (e.g. reducing combined sewer overflow spills) in Berlin, Germany. A key finding was that citizens gained the highest utility in improved water quality from reduced fish die-offs.

DCE has been used to investigate large-scale *GI approaches to flood control* in Hokkaido, Northern Japan (Kim et al., 2021). Households' willingness to pay was greater where interventions supported culturally significant wildlife, wildlife-related recreation and flood control. Relational values of individual identity and place attachment affected choices, with notions of social responsibility furthering understanding of results that cannot be interpreted in terms of economic theory alone. Hérivaux & Coent (2021) used DCE to value benefits, disservices, and preferences for flood risk management NBS retrofits in cities, compared with conservation of existing peri-urban greenspaces, around Montpellier, France. They conclude that households would contribute large amounts through tax increases. Responses varied with income, urban-rural location and perceived importance of ecosystem services, which should be addressed to avoid distributive inequalities.

Street trees and other NBS involving *street-level vegetation* have been studied by Fruth et al. (2019; 2020), who also provide detailed underpinning data tables. Using DCE, they established that households in urban Berlin strongly supported and were willing to pay for urban greening measures, including increasing street-level vegetation and trees – with values being heterogenous as regards socio-demographic and attitudinal perspectives.

Botes & Zanni (2021) also established that there was positive support from citizens for *ground-level street vegetation* in Taipei, Taiwan. However, they found that of the interventions tested including trees, ground vegetation, sidewalks and cycleways, willingness to pay was highest for the latter. The presence of flowers was also strongly valued, but street trees less so. Subsidies for lawn replacement to reduce watering impacts was the subject of DCE valuations by Conrad & Yates (2018). They found that households support for 'more brown than green' lawns could lead to considerable reduction of outdoor water use including through voluntary adoption, depending on aesthetics, size and vegetation choices.

Economic valuation of the impacts of *green walls and roofs* has been undertaken using DCE. Collins et al. (2017) explored the value of green walls and economic value of biodiversity they provide in Southampton, UK. Green infrastructure approaches were compared with conventional walls, with highest levels of utility associated with living walls, followed by green façades. Estimated values of green walls exceeded investment cost and attitudinal characteristics including knowledge of biodiversity and aesthetic opinion were significant factors. Similarly, in Flanders, Vanstockem et al. (2018) assessed the preferences for visual aspects, with experiments indicating that vegetation gaps and weedy species, together with a diverse vegetation have a considerable impact on green roof perception.

Teotónio et al. (2020) found using DCE valuation that citizens were willing to pay more for *accessible green roofs*, and that knowledge of green roof benefits also had such an impact. They concluded that recreational benefit was more important to individuals than aesthetics. On an international basis Manso et al. (2021) investigated values of *green roofs* linked with Covid-19 lock-downs, finding that around 2/3 of respondents missed having a garden and most were willing to pay for green roof access; support levels increased for larger spaces.

Benoliel et al. (2021) used DCE methods to establish citizens' preferences for urban greening (*gardens and green walls*) at Entrecampos Station, Lisbon, Portugal. They found that willingness-to-pay for greening in public transport interfaces was low, and that other improvements such as more seats or safe and comfortable waiting areas were preferred.

The DCE carried out by Netusil et al. (2022) was used to estimate public benefits for a proposed *green roof* program in Portland, USA, for reduced combined sewer overflows, reduced urban heat island effects, and an increase in pollinators such as birds, bees and butterflies. Largest estimated benefits were for reduced sewer overflow spills; respondents preferred green roofs to be distributed around the city rather than just in the city centre.

Urban forestry interventions have also been studied using DCE. Hong et al. (2018) used DCE to establish preferences for urban forest NBS. Participants were willing to pay significant extra amounts to change coniferous forest to broadleaved forest, and to change paved trails into soil-type trails, and to modify steeply sloping trails to relatively flat trails (in order of least to most payments). Results were affected by age and gender of respondents. In Vienna, Austria, Ebenberger & Arnberger (2019) established that visual preference, heat relief and restorative experiences were linked also with *urban forests'* structural biodiversity aspects. Ground vegetation configuration was the most important component as regards visual preferences, with shade being important for heat relief; during hot days, respondents would tolerate a less aesthetically appealing urban forest setting to spend time in the shade.

Davies et al. (2023) studied willingness-to-pay for urban forest ecosystem services in Southampton, UK using DCE. Values and support were adversely affected by the presence of risk around service outcomes, with subjective uncertainty reducing WTP more than objective probabilities.

Willingness to pay for *air quality* impacts of *urban forests and greenspace* interventions have been tested using DCE. In Manila, Philippines, Lagbas (2019) used this method to establish levels of support to protect a created *urban forest* as regards values placed by students on ecosystem services and non-use values. Air quality and temperature regulation were the two most valued services. Liu et al. (2020) established that Beijing residents exposed to higher pollution levels were willing to pay more for small new neighbourhood-level parks in cities; no such effect was found in support of larger or national- scale parks.

Also in Beijing, Zhi-Ying et al. (2021) combined DCE with Delphi method studies, finding that air quality regulation was considered the most important ecosystem service for residents impacting their choices regarding urban forest creation. Residents were willing to pay significant proportions of average annual incomes in order to expand urban forest ecosystems to deliver improved air quality. Finally, Jiang et al. (2023) found that information interventions alter the preferences and willingness of the public to pay for air quality improvement, with women and high-income groups showing stronger support to improve air quality in terms of willingness to pay for improved urban green coverage rate, fewer haze days and reduced morbidity.

Urban agriculture has been less widely studied using DCE. Kyoi (2021) found that in Ishikawa Prefecture, Japan, residents tended to avoid neighbouring urban agricultural GI. Evidence from their DCE was linked with spatial econometrics, finding a 'not-in-my-backyard' phenomenon applied, people preferred urban agricultural land far away from their homes.

More widely, Hagedoorn et al. (2021), investigated the potential of community time contributions to reduce the financial needs of NBS in Ghana and Vietnam using DCE. Time contributions from households were motivated by social capital whilst in general not excluding specific socio-demographic groups in society, such as lower income households.

4.1e. Revealed preferences

This method entails establishing what price consumers will pay to access goods either directly or indirectly, and in relation to urban NBS several methods have been applied to determine revealed preferences, notably hedonic pricing and travel cost methods. Such methods tend to be applied at the city or regional scale, rather than at the very local street, neighbourhood or district scale. For instance, Łaszkiewicz et al. (2019) explored proximity to urban green spaces as a non-tradable good with the use of hedonic pricing method, noting that at the time, the possibility to describe the luxury of green space proximity based on revealed preferences methods had not yet been evaluated. Since then, many studies have performed economic valuations regarding access to urban greenspace using revealed preference studies, but the literature surrounding NBS *interventions* is more limited.

Hedonic pricing method

Chen (2017) explored the values of *urban river restoration* using hedonic pricing. This analysis of environmental externalities of river pollution and restoration in Guangzhou (China) concluded that urban river restoration could reverse negative externalities of polluted water to achieve positive benefits and could increase property values significantly.

Several studies have used hedonic pricing to value on *urban stormwater management NBS* such as *SUDS.* Irwin et al. (2017) investigated whether stormwater management NBS generate co-benefits in Maryland, USA using housing transactions data and exploiting variation in placement and design. Results showed adjacency causes decreases in housing prices and that stormwater basins generated a cost for proximate households. In contrast, Irvine et al. (2020) used hedonic pricing, supported by qualitative surveys, in Geelong, Australia and Singapore, to evaluate benefits related to large SUDS features, finding a significant inverse relationship between the housing sales prices and distance to NBS interventions. Qualitative surveys were in accordance whereby the majority of people appreciated benefits accrued from living near the SUDS.

Hoover et al. (2020) also used hedonics to examine the effects stormwater management NBS such as rain gardens, vegetated roofs, and bioswales on residential sales prices in Omaha, USA. After controlling for confounding factors such as home deterioration and non-stationary location effects, they did not find any statistically significant relationships between housing values and GI. Sohn et al. (2020) also applied hedonics to understand the environmental benefits of SUDS on neighbourhood real estate values, in Houston, Texas. They conclude that living near retention ponds had positive impacts on housing prices whereas detention ponds depreciated housing values.

Jia & Zhang (2021) investigated the economic benefits of *green and blue infrastructure* (GBI) in urban areas in Wuhan, China. They suggest that the closer GBI is to urban residents, the higher the economic benefits are regardless of the area and that the more prevalent and visible green is, the greater the economic benefits. Li et al. (2021) also explored homebuyers' preferences for urban GBI in Guangzhou, China, attempting also to disaggregate impacts of different attributes, including riparian greening, recreation, odour, and river water quality on apartment prices. They found that the first two factors affected house prices positively, the third had a negative impact, and the latter factor had no effect. At the aggregated level, preferences became weakened when district income level increased, whereas district population density played an enhancing role.

Zhang & Dong (2018) assessed the impacts of *street-visible greenery* on housing prices: in Beijing examining location, housing, and neighbourhood characteristics finding that homebuyers preferred to live in areas with higher green views and with large lakes, but that housing prices are affected also by spatial development patterns of the city centre and multiple business centres.

As regards *urban tree planting*, Donovan et al. (2021) used hedonics to examine data from Portland, USA (1990–2019). They found that the number of trees planted was significantly associated with a higher house sales price, although it took at least six years for this relationship to emerge. Tree planting was not merely a proxy for existing tree cover, which had a different impact on median sales price. They conclude that tree planting is modestly associated with neighbourhood-level gentrification. Plant et al. (2017) also evaluated revealed preferences for street tree cover in Brisbane, Australia. Using spatial hedonic price modelling they concluded that homebuyers would pay significantly more for homes in streets with target levels above 50% tree canopy coverage (but see Łaszkiewicz et al., 2022).

For *urban green space* interventions more generally, Engström & Gren (2017) note that the validity of the hedonic pricing approach has been questioned, and proposed amendments to improve its accuracy. They found that in Malmö, Sweden, urban parks have a positive effect on property value and that this effect tends to increase with reduced distance to the parks, but that the hedonic pricing information is not enough to make well-advised decisions in a sustainable planning context, suggesting to complement hedonic pricing using an ecosystem service lens, and taking the surrounding land use configuration into account for optimising the different values of urban parks.

Roebeling et al. (2017) used hedonic pricing simulation to explore not just the impact of NBS on real estate values but also cities' compactness, population densities and demographic distribution patterns, at the Lyon Confluence greenspace project in France. They concluded that the magnitude of these impacts depends on the quality and size of the intervention, social demographics and other infrastructures. In Eindhoven (The Netherlands), Augusto et al. (2020) also applied hedonic pricing to assess urban heat fluxes and urban compaction effects, showing that, in the short-term, NBS have a local cooling effect but in the medium to long-term, a counteracting urban compaction effect due to attraction of new residents.

Iváncsics et al. (2019) used the hedonic price method to explore new urban public park values in Budapest, Hungary started in 2016, finding that the park would pay for itself by 2019. They conclude that without the effect of property appreciation the investment turns positive only by 2061 due to indirect social, economic, environmental benefits. Piaggio (2021) used hedonics to estimate the effect of proximity to and size of urban green spaces on housing market values in San Jose, Costa Rica. The results showed that individuals assign substantial value to the restoration of areas, for house owners only, but not those renting.

Schwarz et al. (2021) examined hedonics data alongside qualitative methods in Leipzig, Germany, finding that green spaces have positive and negative impacts on wellbeing, land markets and choice and qualities of residential location. They conclude that triangulating the qualitative and quantitative research results improves understanding in these contexts.

Wu & Rowe (2022) used hedonic pricing to urban green space associated gentrification in Beijing, China. While green space provides multiple benefits for urban residents, they found that adding new parks can trigger gentrification by increasing nearby housing prices. Their results showed that greenspace creation most affected closest housing prices, but this impact was not proportional to distance, and more natural parks had insignificant effects on housing prices and nearby park disamenities acted to discount premium effects. Finally, Xu et al. (2022) assessed impacts of a *cultural greenway* in Central Beijing, which connects open green spaces and sites of sociocultural value to provide access to living, working and recreational spaces and enhance local social well-being. Using hedonic pricing they found that proximity to the greenway project was positively linked with rising property prices nearby (within 1 km), both pre- and post- project implementation.

Łaszkiewicz et al. (2022) caution against using simple linear distances and distance decay in property prices relative to pedestrian network distance to urban greenspaces, due to observed heterogeneity in the implicit property prices.

Travel cost methods

The travel cost method uses distance travelled to a green site (often for recreation) as a surrogate for demand for a non-market good, with an economic equivalent. Such applications tend to be rare in urban contexts, and are especially so for NBS.

Bertram & Larondelle (2017) applied the travel cost method to assess demand for a large *urban forest* site at Grunewald in Berlin, Germany to establish consumer surplus with approximately €15 per visit. They conclude that despite its inherent limitations, the method can provide a powerful tool to monetise the benefits of urban forest recreation. Herwanti et al. (2021) also studied the economic value of urban forests for tourism in Lampung, Indonesia, an alternative tourism spot easily accessible by urban communities. Drawing on travel costs data they conclude that the role of urban forest values can be further improved by protecting and enhancing biodiversity, selecting appropriate tree species, developing urban forest tourism facilities and providing education.

Kim et al. (2021) used the travel cost method to understand recreation demands and impacts of *restoring large urban green spaces* in the Sapporo, Japan. Recreation demands were estimated for 21 green infrastructure interventions showing that few large urban green spaces had high consumer surplus and that visitor characteristics affecting the number of visits were complex including gender, age, families, car access, and use for walking, running or observing nature.

At Oulu in Finland, Mäntymaa (2021) explored economic impacts of *urban river restoration* including fish habitat creation and improvements in cultural and visitor services, finding that improvements of each service separately tended to increase the value between 14% and 21%, and of all services simultaneously by 66%. Visitors from lower income households valued the park more than wealthier individuals. Increasing respondents' awareness had positive impacts on visits and values of the restoration, which they conclude to have been profitable.

Cetin et al. (2021) used travel costs to explore values of urban rivers at Ömerli, Istanbul. Visits depended on three significant factors: visitors' recreational habits, satisfaction and experience with nature, and urban environment. They found that consumer surplus was eight times the average travel cost per person per year.

Exploring the impacts of *green walls, roofs and corridors*, Zhang et al. (2020) used the travel cost method in Guangzhou, China to explore residents' willingness to pay (WTP) for the use and maintenance of these small urban greening interventions. They concluded that 80% of residents were willing to pay to use and maintain the greening measures providing significant nonmarket and human wellbeing value for local households.

4.1f. Land values and land valuation

Land values can provide an important tool in the economic valuation of urban NBS, and can be investigated through stated preferences or revealed preference techniques. Given the importance of urban NBS land-take dynamics, this form of valuation also deserves attention in its own right.

Kozak et al. (2020) explored relationships between land value, hydraulic performance, and politico-institutional conditions around NBS scenarios in Buenos Aires, Argentina. They found that even in very dense and impervious urban basins it is economically viable to implement blue-green infrastructure, including the daylighting of culverted watercourses.

Cuvi & Vélez (2021) explored relationships between land value, poverty and ethnic self-identification in relation to the need to reformulate urban spaces quantity, distribution and accessibility of parks in urban areas of Quito. They found that green is not evenly distributed and that neighbourhoods with the highest proportions of urban green space are usually those with the highest land value and least poverty (no clear relationship with ethnic background was found). Likewise, through land value mapping in Greater Mexico City, Molar-Cruz (2022) also found higher land value in areas where environmental features were present that improved ecosystem services.

Interestingly though, Morgenroth et al. (2017) found in Christchurch, New Zealand that tree removal was more prevalent on properties with higher land value, serving to remind that relationships between land prices, GI and development patterns are far from simple or straightforward. Picard & Tran (2021) used empirical data at the EU scale to explore the impacts of small urban green areas' amenities, which affected residential choices, land consumption and land rent. They conclude that land share dedicated to small urban green areas results from the trade-off between land value and population density, and depends on distance to the city centres.

Dyca et al. (2020) examine the prospects for using Land Value Capture (LVC), specifically the application of transferable development rights instruments to promote investment in blue-green infrastructure. Identifying critical distributive-justice implications as regards land management decisions, they found that whilst these mechanisms have the potential to provide funding, their likely success depends on the specific legal, market and urban development contexts. In the UK, Buck et al. (2021) also considered the role of LVC in the form of negotiated developer contributions for financing ecological mitigation programmes. They highlight cultural and behavioural challenges, noting that local authorities' responses to financial austerity and development markets heavily influenced developer contribution practice.

Also in the UK, Wild (2017) established that although urban NBS interventions would deliver a wide range of ecosystem services and that householders were willingness to pay for those services, underlying land values meant that regeneration projects would remain unviable in areas of weak or failing land markets. Although the schemes were profitable at the community, city and national levels, without government funding, private sector investment would be unviable and unlikely to deliver those ecosystem service benefits.

4.1g. Incentive analysis

Incentives can be financial and non-financial, and are closely related to personal behaviours and motivations; as regards NBS programmes and projects, they tend to focus on public sector interventions, usually in the form of remuneration or cost savings. Incentive analysis has not been widely applied in the realms of green infrastructure, urban greening and so on but can provide important insights into future scenarios, prospects for NBS and uptake of behaviours deemed desirable to promote biodiversity and urban ecosystem services.

As well as applying choice experiments, Conrad & Yates (2018) analysed incentives for *urban lawn replacement to reduce irrigation* in the Okanagan Basin, Canada. They found that modest subsidies could lead to reduced outdoor water use through voluntary adoption; more extreme water conserving lawn configurations could be more effective in reducing overall outdoor water use – even though adopted by a smaller percentage of residents.

Fu et al. (2019) analysed scenarios to calculate optimum stormwater runoff abatement credits and allocations to assist in decision-making around *GI* investment in Ohio, USA. They proposed a system whereby the water catchment management authority could encourage all parcel owners to install suitable GI or purchase credits from the market, using these funds to provide investments in regional detention systems and yet still reducing net flows.

Boguniewicz-Zabłocka & Capodaglio (2020) examined impacts of fiscal or fee incentives in terms of uptake of *SUDS* in urban catchments in Silesia, Poland. In particular they looked at households' water reuse using retention tanks and rain gardens, both of which offered financial returns depending on the degree of possible water reuse (lower water bills) and levels of incentives, providing prospects for reduced environmental impact and costs of stormwater overflows and sewer systems. Godyń et al. (2020, 2022) have also analysed incentives in Poland for *sustainable urban rainwater management* in residential developments, providing a financial feasibility assessment and motivational rainwater fee system efficiency analysis. They found that national incentives for SUDS to encourage rainwater retention had lower non-incentive rates than municipal fee reductions; the former gave a payback period of almost 100 years as compared with investment recovery within 12 years due to the local municipal scheme.

Claron et al. (2022) combined *urban ecosystem services* mapping with an examination of incentive-based instruments to support the geographical targeting of measures to reverse and prevent soil sealing. They contend that this spatialised return on investment approach can help improve the cost-effectiveness of incentive-based conservation instruments.

Finally, in Oslo, Norway Wilkerson et al. (2022) modelled reverse auction-based subsidies and stormwater fee policies as policy instruments to promote *SUDS* uptake in private properties. Policy effectiveness depended on realism in communications with landowners about SUDS performance, as well as targeting of municipal subsidies to reach landowners without intrinsic interests in water management. Under certain conditions, lower municipal economic incentives could outperform higher subsidies and lead to more sustained uptake.

4.1h. Net present value and cash flow

Net present value provides a useful tool to understand costs and benefits of interventions such as NBS that happen over differing or longer time frames, and impacts in the current value of future cash flow (and the time value of money). Few cases are reported in the literature of its application to NBS, whereas capital and operational costs do tend to cover discounted cash aspects, e.g. in water services.

As described above, in Poland, Godyń et al. (2020, 2022) analysed incentives promoting uptake of *SUDS and water reuse*; as well as analysing incentives they used net present value (NVP) to address possible discounts in fees and subsidies in their analysis of variance.

In Nanjing, China, He et al. (2021) used NPV methods in ascertaining that payback periods for different types of *green roofs* (extensive, semi-intensive and intensive) finding that none of the three could recover investments cost through energy-saving benefits alone during their 40-year life cycle. Similarly, Jato-Espino et al. (2022) used NPV along with life cycle assessment and qualitative methods to investigate SUDS performance in Querétaro, Mexico, finding that maintenance costs and life expectancy hindered economic feasibility.

However, Nordman et al.'s (2018) cost-benefit assessments of SUDS in Michigan, USA used benefit transfer approaches to estimate the net present value (NPV) of capital, operations, and maintenance costs, as well as the direct and indirect benefits. Their study addressed not just stormwater runoff quality and quantity but also air pollution, aesthetics and carbon sequestration, demonstrating that conserved natural areas, street trees and bioretention rain garden systems all yielded higher NPVs than porous asphalt. Similarly, Johnson & Geisendorf's (2019; 2021) examinations of cost-benefit of local-level SUDS (see earlier sections) used NPV in analyses covering water quality, water quantity and urban heat island impacts, demonstrating economic feasibility and substantial social value.

Although active *management of invasive pests* cannot really be classed as an NBS, still, Hauer et al.'s (2020) use of NPV in investigating Dutch elm disease also gives important insights as to how this technique can be useful in understanding the value of 'invest to save' maintenance strategies.

In their socio-economic assessment of *green roofs and living walls,* Matos Silva et al. (2019) used NPV to investigate alternatives for the railway station retrofit. Whilst all five greening alternatives were found to be economically feasible, their sensitivity analysis revealed a high degree of influence of discount and inflation rates impacts on highly variable NPV values. Idczak et al. (2019) used the discounted cash flow method (similar but not the same as NPV) in combination with benefit transfer and contingent valuation in their assessment of impacts of urban ecosystem services in their economic appraisal of urban regeneration projects (see contingent valuation section).

Finally, Quaranta et al. (2021) investigated NPV values of water, energy and climate benefits of urban greening across Europe under different climatic scenarios. Net of the monetised benefits, the cost of greening 26,000 km^2 of urban surfaces in Europe was estimated at around 60 € per year, per urban resident, even without valuing the additional impacts of urban greening related to biodiversity, water quality, health, or wellbeing benefits.

4.1i. Life cycle costs

Abdeljaber et al. (2022) used life cycle assessment (LCA) and life cycle cost analysis (LCCA) within an environmental and techno-economic performance assessment of multiple SUDS type interventions (as compared with conventional stormwater pipe drainage systems). The LCA and

LCCA results revealed that the pipe drainage system was the least beneficial or cost effective in terms of environmental impact, runoff performance and financial burdens.

In five different US cities, Bixler et al. (2020) investigated the economics of GI systems from a spatial perspective, also addressing opportunity costs related to land and property tax, material costs and labour rates. GI systems were compared with conventional hard infrastructures over whole life cycles, comparing nutrient removal and total stormwater reduction. Place-specific land- and tax-costs had significant impacts, and they conclude that GI systems recommendations need to address this to achieve greatest cost-effectiveness. In São Carlos, Brazil, dos Santos et al. (2021) found differing results using LCC versus stormwater volume treatment performance alone. This joint assessment is expected to better assist the decision-making processes for sustainable stormwater management, balancing flood protection and costs.

Lu et al. (2022) used flood risk modelling and life cycle costs to identify low impact development or LIDs (akin to SUDS) locations and optimal configurations in Singapore. Using 1D-2D hydraulic models coupled with surrogate (Gaussian) process techniques they established that optimised design LIDs could reduce damage cost greatly beyond their own life cycle cost compared with conventional drainage by reducing the urban imperviousness. In Beijing China, Mei et al. (2018) used life cycle cost analysis and storm water management modelling to undertake integrated assessments of *retrofitted GI for flood mitigation* (bioretention, vegetated swales and porous paving). Whilst results confirmed the cost-effectiveness of GI for flood mitigation, they concluded that even under the most beneficial scenario the GI's improved hydrological performance could not eliminate flooding.

Qiu et al. (2021) investigated urban water NBS in Paris, France by examining life cycle costs and reductions of peak flow and total runoff volume. Considering the NBS scenarios under the strongest rainfall events, they established that concentrating NBS downstream within the urban catchment would be most cost-effective. Tavakol-Davani et al. (2019) used life-cycle cost analysis to assess urban water NBS (GI: permeable pavements, green roof and bio-retention) in combination with both basic runoff volume effectiveness and water budget restoration coefficients. For equivalent life-cycle costs the latter hydrologic goal was more effective in identifying options delivering greater co-benefits of flood risk management, evapotranspiration, air quality, and water quality.

Tudiwer et al. (2019) used life cycle costs in their assessment of the cooling production costs of a south-facing green façade in Vienna. Three independent parameters affect these cooling production costs: the evaporation capacity of the green façade, the total costs for the green system (including construction and planting) and the number of summer days. They conclude that this kind of cooling is effective and efficient in counteracting Urban Heat Island effects.

In Qian'an City China, Wang et al. (2022) studied the effectiveness and economic value of SUDS including sunken green space and infiltration ponds, using life cycle costs and stormwater management models. The results indicate that in semi-humid regions, sponge cities approaches can be effective in rainwater regulation, collection, storage and use. Xu & Zhang (2019) used life cycle cost analysis to evaluate the environmental and economic impacts of alternative bioretention system configurations relative to their flood control and nutrient management capabilities. Exploring trade-offs between impacts of eutrophication, ecotoxicity, fossil fuel depletion, and global warming potential, a main conclusion is that suitably deep internal water storage zone is critical to effective performance.

Zidar et al. (2017) examined life cycle costs of GI at an urban agriculture site on vacant land in New Jersey, USA. Focusing on operation and maintenance, they explored how revenues might offset costs. Unusually, the study examined how maintenance costs might be met to sustain co-benefits including reduced combined sewer overflow spills, flooding and heat island impacts, whilst enhancing capacity, green jobs, and health and wellbeing outcomes.

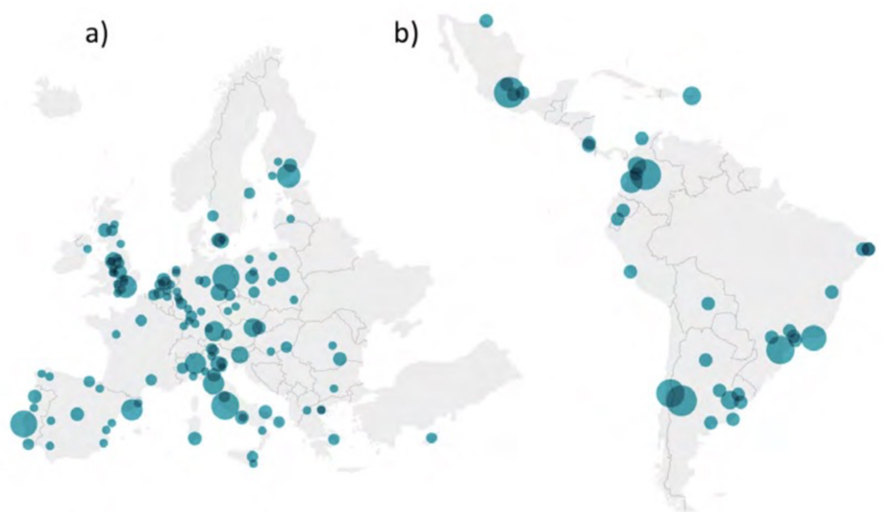
4.1j. Other economic valuation methods

Additional economic valuation methods are described in Ozemiroglu & Hails (2016). Of these, explicit references could be found in the literature relating to averting expenditure modelling and NBS (or NBS-like interventions). *Replacement costs* methods have been used in modelling NBS for stormwater management (Silvennoinen et al., 2017; Jarvie et al., 2017; Assaad et al., 2023, although not strictly in the terms described by Ozemiroglu & Hails (2016) and in relation to the restoration and conservation of urban Atlantic Forest in Brazil (Medeiros et al., 2019, linked with present value). Finally, in Beijing China, Wong et al. (2017; 2018) has examined *production function* in efforts to understand blue-green infrastructure benefits, by quantitatively linking ecohydrological processes to human benefits. Modelling the benefits of seven artificial lakes and wetlands, they evaluated water storage and local climate regulation (human comfort and evapotranspiration). Noting the vulnerability of the lakes and wetlands to drying and eutrophication, they recommended reductions in nutrient levels, deepening to increase water storage, and tree planting in order to increase shade and improve thermal comfort.

4.2. Desk-based work: links between economic valuation methods and NBS impact indicators

In developing an inventory of economic valuation methods linked with specific indicators of NBS impacts, 416 peer-reviewed publications were analysed (between September 2021 and April 2022), using the results of reviews undertaken by Amaya-Espinel et al. (2021) and Wild et al. (2020). It should be noted that the literature set used in this part of the research project (the case study database or 'inventory review') was not the same as the formal review described in Figure 1. This is because deliberate attempts were made by Amaya-Espinel et al. (2021) to draw on a wide set of literatures including references and cases from Central and South America and Europe (Figure 2), covering NBS and closely related concepts. That report produced deeply contextualised case studies, also summarised online at: https://www.conexusnbs.com/case-studies.

Figure 2. Locations of NBS cases in cities in (a) the European Union (EU) and (b) the Community of Latin American and Caribbean (CELAC) States (Amaya-Espinel et al., 2021).



A total of 41 different impact indicators were recorded in the database of over 400 cases drawn together by Amaya-Espinel (2021). These indicators related to many different criteria addressing a vast range of societal challenges. However, most studies addressed only a few indicators (*mean*: 3 indicators). Economic assessment methods described in the articles included cost benefit analysis, benefit/ value transfer, contingent valuation, discrete choice experiments, incentives analysis, cash flow, hedonic pricing, land values, life cycle costs, travel cost methods, willingness to pay, and net present value.

Table 1 provides an overview of the impact indicators covered by publications analysed in the inventory review, in relation to societal challenge themes identified in Dumitru & Wendling (2020).

Table 1. Case study impact indicators, aligned with EC Handbook societal challenges (Dumitru & Wendling, 2021)

NBS Impact Handbook challenges areas (2020)	Indicators used in manuscripts (with number of studies, in brackets)
Climate resilience	Biomass provision, incl. timber & fuel (10); $C0^2$-GHG storage, reduction & mitigation (30); Disaster risk reduction, natural hazard reduction (8); Energy efficiency - avoided emissions (7); Evapotranspiration (18); Heat, urban heat island (85); Resource efficiency (6); Shade provision, reduced solar irradiation (21); Soil quality (8); Tree cover & vegetation cover, incl. NDVI normalised difference vegetation index (86).
Water management	Disaster risk reduction, natural hazard reduction (8); Drought prevention - water resources (5); Evapotranspiration (18); Flood risk management (40); Infiltration & soil sealing (18); Runoff-flow-retention (48); Water quality, water pollution & waterbody conditions (22).
Natural & climate hazards	Disaster risk reduction, natural hazard reduction (8); Drought prevention - water resources (5); Flood risk management (40); Runoff-flow-retention (48);
Green space management	Biomass provision, including timber & fuel (10); Greenspace access, visits, use, accessibility (62); Food supply & provision (25); Human-nature experience (18); Land use change incl. urban sprawl (27); Recreation & amenity (60); Tree cover & vegetation cover, incl. NDVI (86); Soil quality incl. erosion (8).
Biodiversity enhancement	Biodiversity, incl. pollinators & biological control (79); Soil quality incl. erosion (8); Ecological structural & functional connectivity (25).
Air quality	Air quality incl. air pollution & allergens (79); $C0^2$-GHG storage, reduction & mitigation (30).
Place regeneration	Aesthetics, incl. attractiveness (47); Energy efficiency - avoided emissions (7); Place - quality, sense of, attachment, identity (24).
Knowledge & social capacity building	Dialogue incl. knowledge exchange (9); Educational opportunity & provision (7).
Participatory planning & governance	Dialogue incl. knowledge exchange (9); Governance (26); Participation & salience (26); Trust (4).
Social justice & social cohesion	Environmental in/justice (11); Population density (13); Safety-security-danger-crime (12); Social capital, cohesion, connection (19); Social inclusion (12).
Health & wellbeing	Human health & morbidity (15); Human-nature experience (18); Noise & sound pollution, insulation (20); Quality of life (19); Wellbeing, stress relief, restorativeness (36).
Economic opportunities & green jobs	Socio-economic status & deprivation (35); Tourism (6).

Notes: Indicators in the NBS Impact Handbook (Dumitru & Wendling, 2021b) often appear in/across multiple societal challenge area categories; here numbers given include the same studies for indicators duplicated in the Handbook, and sub/totals are not provided since studies used multiple indicators.

Clustering of impact indicators according to the 12 societal challenge areas assisted with validation and supported the mapping of indicators of interest in specific cities; duplication was a significant issue, whereby indicators nested under multiple 'parent' challenge areas (ibid.) in several instances. Of all cases analysed in the database (Amaya-Espinel et al., 2021), 62 reported the application of monetary valuation methods. In other words, the vast majority of NBS cases in this database did not entail monetary valuation. Table 2 shows the 'top 10' indicators addressed by valuation studies within that subset of manuscripts. Several papers applied more than one indicator and/or more than one valuation methodology (thus Table 2 does not include sub/totals).

Most of this subset of studies (entailing monetary valuation) addressed physical-environmental aspects only (see Table 2). Monetary valuation studies rarely focused on indicators covering socio-cultural, political and governance aspects (e.g. participation: 1 reference; social inclusion: 3; quality of life: 3). Valuations tended to be clustered together with indicator types, and vice versa. For instance, travel-cost methods were commonly applied for projects addressing recreation, biodiversity, land-use change and amenity. Hedonic pricing was often applied in relation to greenspace and vegetation cover. Discrete choice experiments often addressed aesthetics and recreation. CBAs were broadly applied across indicator types.

Table 2. Which indicators were most often addressed by economic valuation studies of NBS

Indicators (top 10 indicators covered by valuations)	**Monetary valuations**	**Total number of studies**
Tree cover & vegetation cover (including NDVI)	18	86
Recreation & amenity	16	60
Aesthetics, including landscape attractiveness	15	47
Air quality, air pollution & allergens	14	79
Biodiversity, pollinators & biological control	14	79
Flood risk management	13	40
Runoff of urban water (flow, retention, detention)	9	48
Heat, urban heat island effect	9	85
C02-GHG storage, reduction & mitigation	8	30
Socio-economic status & deprivation	8	35

4.3. Focus groups with cities: co-producing understanding of impact indicators and valuations

Prior to the Conexus conference held in São Paulo, Brazil in May 2022, abstracts of publications reporting economic valuation of NBS were sent to the Conexus city Life-Lab. Information on the societal challenge areas and impact indicators of relevance to each city helped to provide a focus for this exchange. Lists of the criteria used in this filtering process are described below[2].

- For Barcelona, Spain, challenge areas of interest included greenspace management, air quality and social capacity. Indicators of relevance as regards valuation were greenspace accessibility and coverage, food production, air quality, and structural and vegetation biodiversity.
- In Bogotá, Colombia, societal challenge areas in focus included knowledge and social capacity, water management, climate resilience, greenspace management, place regeneration, social justice and cohesion and biodiversity enhancement. Impact indicators included environmental education, social learning, trust, water quality, place attachment, soil carbon storage and biodiversity.
- As regards Buenos Aires, Argentina, key challenge areas of relevance to valuation were water management, air quality, knowledge and social capacity, biodiversity enhancement, and

[2] NB these lists should not be viewed as comprehensive and do not represent the entire range of interests in those cities' NBS programmes and projects, nor are the lists presented in any order of importance.

participatory planning and governance. Indicators in focus included participation openness, air quality, water quality and pollution, water quantity and biodiversity, particularly vegetation.

- In Lisbon, societal challenge areas focussed on green space management, place regeneration, participatory planning and governance, biodiversity, and knowledge and social capacity. Key indicators included greenspace coverage, reclamation of derelict land for NBS, uptake in terms of number and diversity of NBS types, environmental justice, biodiversity and knowledge exchange.
- For Santiago, impact challenge areas in focus were climate resilience, health and wellbeing, knowledge and social capacity, biodiversity, greenspace management, social justice and capacity building. Associated indicators were greenspace accessibility, greenspace coverage and share per inhabitant, environmental education and pro-environmental behaviour, urban temperatures, public-private partnerships, wellbeing, safety and security, biodiversity and GI connectivity.
- The São Paulo Life-Lab focus was on challenge areas including climate resilience, place regeneration, biodiversity, and participatory planning and governance. The key impact indicators related to carbon sequestration and storage, perceived quality of space, urban temperatures, vegetation biodiversity, openness of participation processes, recreational value, evapotranspiration, and measures relating to tree growth including carbon flux and energy balance.
- In Torino, Italy, challenge areas related to climate resilience, water management, greenspace management biodiversity and air quality. Particular impact indicators of interest included heat mitigation, greenspace accessibility, air quality, and water runoff, quality and permeability.

During the Conexus conference plenary session held on 26th May 2022, 39 participants responded to the Menti poll relating to societal challenges addressed by the cities' NBS programmes and projects. Respondents identified key criteria and indicators to understand what they considered to be the most important impacts and co-benefits of those interventions in the Conexus cities (Fig.3).

Figure 3. Overview of societal challenges of interest and key impact indicators across 6 Conexus cities

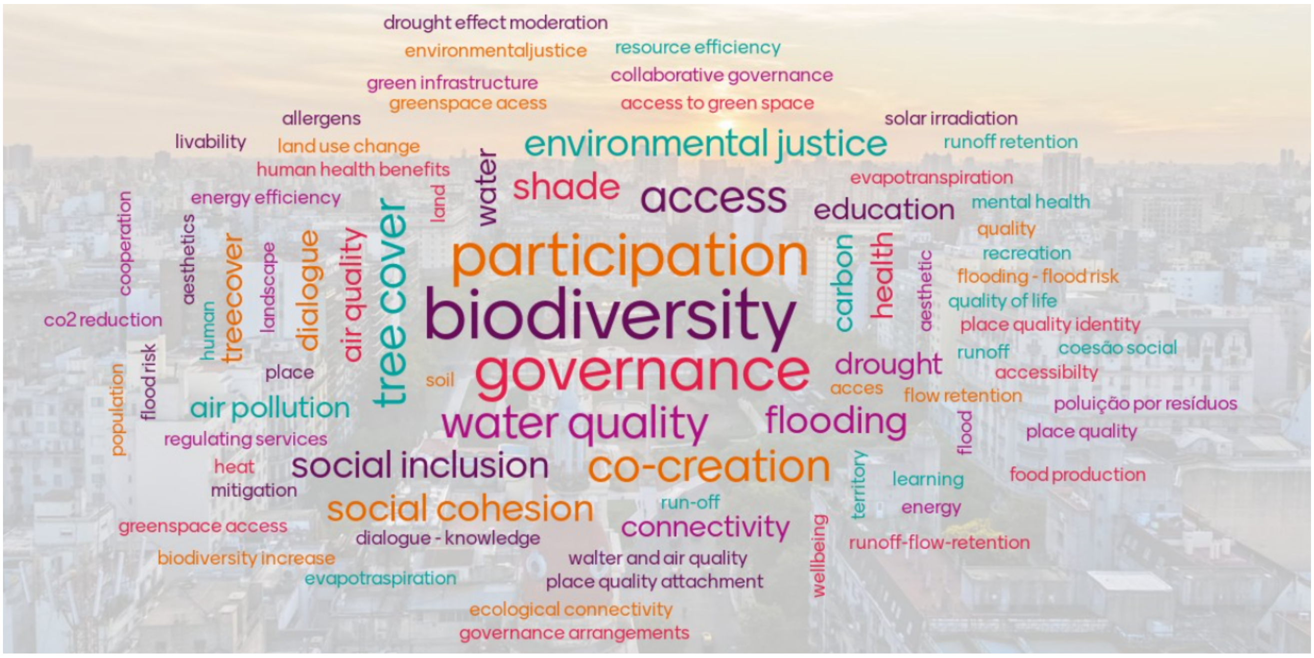


Table 3 provides a summary of the valuation methods that participants in the São Paulo workshop (26th May 2022), considered most relevant for Conexus NBS pilots and showed most interest in.

Table 3. Most relevant valuation techniques for each life lab identified during Sao Paulo workshop.

City	Most relevant techniques
Barcelona, Spain	CBA focusing on health and wellbeing; WTP using Choice Experiments including visuals
Bogotá, Colombia	CBA; Contingent Valuation; WTP
Buenos Aires, Argentina	Hedonic pricing; CBA, including flood risk management and water quality
Santiago, Chile	Land values; Multi-objective optimisation (multi-criteria analysis)
São Paulo, Brazil	WTP and Choice Experiments using visuals; CBA – socio-economics of greenspace access
Torino, Italy	WTP (pilot scale); Urban ecosystem services - benefit transfer (broader scale).

Notes: WTP: willingness to pay; CBA: cost-benefit analysis. Lisboa, Portugal staff were unable to attend the workshop.

4.4. Semi-structured interviews to understanding how Conexus cities view monetary valuation of urban nature and NBS – including if and how economic assessments are applied

Results from the semi-structures interviews with contact persons in the local municipalities and regional government organisations, provide insights into how cities are addressing the economic valuation of multiple benefits of urban NBS (and related interventions). Table 4 summarises which of the Conexus cities have been using economic valuation, for what purpose and within which contexts. It also provides details of techniques, benefits and indicators applied, where relevant. Table 5 describes the broader themes and sub-themes relevant in each city, based on our semi-structured interviews with participants. Labels used for the broader themes, derived bottom-up from analysis of the transcribed discussions, include “Decision-making”, “Economic valuation of benefits”, “Barriers and opportunities “and “Financing for urban nature”.

Table 4. Summary of responses of semi-structures interviews.

Cities	Participant ID	Economic valuation	Purpose of valuation	Techniques	Benefits	Indicators
Bogotá, Colombia	Participant 1	Yes	Support public policies	Contingent valuation	Carbon sequestration	Carbon removed or stored
	Participant 2	No	x	x	x	x
	Participant 3	No	x	x	x	x
Buenos Aires, Argentina	Participant 4	Yes	Support public policies	Hedonics	New Economic Opportunities	Mean land and/or property value in proximity to green space
Lisboa, Portugal	Participant 5	No	x	x	x	x
	Participant 6	No	x	x	x	x
Santiago, Chile	Participant 7	Yes	Support public policies	Did not know	New Economic Opportunities	Use of ground floor building space for retail, commercial or public purposes in the area surrounding created park
	Participant 8	No	x	x	x	x
	Participant 9	No	x	x	x	x
São Paulo, Brazil	Participant 10	Yes	Environmental assets of the city	Emergy Valuation (Odum, 2000)	Water infiltration	Thermodynamics
	Participant 11	No	x	x	x	x
Torino, Italy	Participant 12	No	x	x	x	x

Table 5. Themes and subthemes identified on semi-structured interviews

Broader themes	Sub-themes	Examples
Decision making	Siloed approaches	“(…) the innovation service acts a bit as a promoter, as internal project manager, as the stimulator, as the enabler. But clearly, all opinions of technical competence remain with the correct departments. We are responsible for the overall expenditure concerning the project goals, so generally, the physical works of the green area remain within the competence of the green area department” (Participant 12).
		“(…). So, [the green department] has the capacity to calculate carbon inventories, nitrous oxide inventories, but it has no influence on political-administrative decisions in this area of transport (…)” (Participant 11).
	Economic valuation of benefits	“(...) the environmental patrimony division wanted to do an economic valuation for the record, so they could say: look at the parks in São Paulo, they provide environmental services worth so many billions of reais or they are worth so many billions of Reais. The prioritisation of new investments is being done by another plan” (Participant 10).
		“(...) I understand that they [the water company] evaluate alternatives, in which they evaluate the scenario without SUDS and the scenario with SUDS. But as far as I understand it, they don't take into account the environmental benefits in monetary terms to make that decision, the decision is more about the capacity of the system. If the system has the capacity and the conventional system is cheaper, they go that way, but if the issue is that the capacity in that area is not sufficient, they consider SUDS. But the issue of assessing the benefits for decision making is just starting so far" (Participant 2).
	Short-term decision-making cycle	“(…). When we work with natural resources, we don't work by electoral cycles. And the decision right now is made in four-year cycles. (…) We live in a society of immediate reactions and therefore all these investments that are made for a longer period are very difficult to make a decision” (Participant 5).
Economic valuation of benefits	Added property value	“(…) we use hedonic price models to determine in the different areas of the city the influences of the different urban facts on the cost of selling a flat, so we know that if it is near a certain green space, you will pay more, or a flat will be more expensive if it is near a green space or if it is near an underground station” (Participant 4).
	New economic opportunities	“The measurements of the economic parameters of the tool have to do with (...) how the park can generate local economies, how it can promote work in the communities, how it can be a platform that generates income for the communities. We measure whether the park has spaces to support fairs, event centres that generate local economies, for example" (Participant 7).
	Carbon credit	"No, there is no valuation of NBS, what is done at the national level, and what is established, is carbon sequestration. In fact, there is a social price per tonne of carbon, but it is very low, so it is marginal" (Participant 9).

Barriers and Opportunities	Reliability of data	“(...), the problem we have encountered is the availability of data to make those evaluations. So, we have made some attempts to take into account the CO_2 emissions from the trees, and to account for them and include them as another variable in this model, but we do not have the measurement data that would allow us to evaluate them more precisely (...)" (Participant 4).
		"There is a great uncertainty in any evaluation of monetisation, so it doesn't make sense to come in with big IT resources or to do a very big survey for each park, for each green area" (Participant 10).
	Monetisation of nature	"However, it is an issue if it [the valuation] is only economic because there is a tendency to monetise nature. So, it is complex, because, in the end, we want to achieve a specific objective (…). So, it [the valuation] is [negative] if the monetary valuation leaves out the main issue, which I think is the improvement of the ecosystem and ecological enhancement” (Participant 8).
	Lack of expertise and knowledge	"Well, I think that as such, [the economic valuation] it is a tool that not everyone knows how to use. So, I think that this is a challenge and, as I said, I think that to make a good economic assessment, you must know the sector very well and you need time, you need resources" (Participant 1).
		"So, the first challenge is which indicators I'm going to bet on, how those indicators are measured, who monitors them and how they are put into money and how I measure the impacts" (Participant 3).
	Communication tools	"I have been working more on the topic of adaptation and it is very important to communicate and try to understand what the costs are of not adapting, right? If we didn't do anything, what does it cost us? It's very important to quantify this for decision making, (...) because it may or may not give more strength to governments, local and national authorities, to really move forward or not, and stop pretending that it's for the next ones, right?" (Participant 6).
	Holistic methods of assessment	"(…) I cannot simply arrive and make an economic assessment without also knowing how it is at the social level, without knowing how it is at the ecological level. I think it is like an umbrella that is always needed from all three to be able to give good results. So, I believe that the challenge is perhaps to find the three methods at the same time, that I also have ecological information, that I have social information to be able to obtain data” (Participant 1).

Financing for urban nature	Increase in budget for urban nature projects	“Today, a regular source that has been approved year after year, it’s a public source, which is a fairly large budget, and which has been growing over the years” (Participant 7).
		“(…), our budget is increasing more and more, society demands more and more and there is also more criticism and demands on our work (…)” (Participant 11).
	Differences between Latin America and Europe in accessing international funding	"(...)I don't remember cases or at least I am not aware of cases where money has come from outside to finance these projects (...) " (Participant 4).
		“(…) there is funding, including through European programmes and the budget, the partnership with the State, or in partnership with the district. So, there are several partnerships to try and reconcile financing to undertake major works. I'm talking about a drainage plan for Lisbon, for example, which is a huge undertaking, perhaps millions... and therefore this type of project has European capital, municipal capital, State capital, and now PRR[3] capital, so several funds are being lent (…)” (Participant 5).
	Public-private finance	“(...) in these last years since 2020 approximately, a management instrument has been developed which is called "*convenios urbanísticos*". What these urban development agreements do is to negotiate with the private party against, for example, a person who wants to build a building with different characteristics to those allowed by the code in an area where it is justified to build with more height or other things, the government says: Well, I allow you to build this with certain conditions, but I allow you to build these floors, in other words, in exchange, you have to give me money or green spaces” (Participant 4).
		“(...) an important source of funding is sometimes private funding, that which comes through, for example, banking foundations. We in Turin have two large bank foundations: Fondazione CRT, and Fondazione Compagnia di San Paolo. In other Italian territories, there are others, so it is quite a present form of financing. And these foundations have increasingly focused on nature-based solutions, somewhat in line with European priorities" (Participant 12).

[3] Plano de Recuperação e Resiliência", which translates as "Recovery and Resilience Plan", a national programme in Portugal, lasting until 2026. The Plan will implement a set of reforms and investments aimed at restoring sustained economic growth, supporting the goal of convergence with Europe over the next decade (https://recuperarportugal.gov.pt/?lang=en).

5. DISCUSSION

5.1. Links between economic valuation methods and NBS impact indicators (desk-based work)

A most striking finding in our work to create an inventory of monetary valuation methods relates to the vast diversity of indicators that have been applied to understand the various impacts of NBS projects and programmes, in diverse settings. Early on in the evolution of the concepts and policies, Pauleit et al. (2017) note that the term '*nature-based solutions'* represents a useful umbrella term for several valuable intervention types. It is also clear that these multiple intervention types are accompanied by a diversity of impacts and that there has been significant innovation in the development of methods to assess their co-benefits and negative impacts.

In this respect, our research findings are in keeping with Dumitru & Wendling's (2021a) guidance on impact assessment. Many of the indicators reported in the peer-reviewed literature match well with areas of focus set out in their (2021b) Appendix of methods at the level of specific indicators and attributes. However, from our research, it is less clear what are the prospects for the holistic and comprehensive assessment of NBS, addressing multiple indicators covering a wide range of domains (social, cultural, economic, technical, environmental etc.). An important limitation is that the literature from which the selection of articles was drawn deliberately incorporated references from Caribbean and Latin American cities (Amaya-Espinel et al., 2021), and this may have affected our results. Most of the articles reviewed focussed on few co-benefits (in contrast with Raymond et al., 2017), few studies addressed multiple impacts (fewer still for those involving monetary valuation (e.g. Escobedo et al., 2015; Langemayer et al., 2015; Kozak et al., 2020).

As regards monetary valuation methodologies applied, we also found evidence of the application of economic assessments from within this literature set, but the methodologies did not correspond particularly closely with methods set out in the guidance. Why does this matter? Dumitru & Wendling (2021) offers "a comprehensive NBS impact assessment framework… indicators and methodologies to assess impacts of NBS across 12 societal challenges". Notably, 2 of those 12 criteria have an economic theme i.e. 'place regeneration' and 'economic opportunities & green jobs', but the coverage of monetary valuation methods is not particularly comprehensive. In this respect, it is recommended that the Appendix of methods (Dumitru & Wendling, 2021b) could be updated to include synopses of applied valuation techniques and it is hoped that this research can be helpful in contributing to the guidance. Useful clues as to the applicability of economic assessment methods can be derived from the clustering of the particular techniques around different types of NBS project goals (such as recreation, vegetation cover and so on).

Other key findings from this part of the project (desk-based research; creation of the inventory) related to the *kinds* of impacts that tended to be assessed in relation to monetary valuation of NBS projects. The top 10 indicators most often addressed in peer-reviewed articles reporting economic analyses are heavily weighted towards physical-environmental and technical outcomes. We return to this theme in the subsequent section, as regards the Conexus cities' priorities for NBS impacts.

Very few published studies examined in this part of the project involved economic assessment of impacts relating to the social, cultural or political domains. Placing an economic value on such outcomes can be problematic, especially for themes such as capacity-building, where important measures of success relate to inputs and processes, as much as outcomes that can be quantified and converted into monetary values. Others have concluded that monetary valuations should only be used in conjunction with other forms of data and broader conceptions of values; this is not a new finding (see Kallis et al., 2013; IPBES, 2022).

However, this gap may also relate to blind spots in the development and application of quantifiable indicators relating to social, cultural and political outcomes in the NBS literature. The need for improved governance indicators and their application to NBS projects has been highlighted previously (van der Jagt et al., 2022) despite being a major focus for innovation in NBS projects such as those funded through Horizon 2020 (e.g. see Wild et al., 2020).

Vasquez & Dobbs (2020) identify the lack of economic valuation of NBS benefits as a key barrier in their development and implementation. We may cautiously add that a specific challenge is to establish what scope of impacts economic valuations should address. It is not yet clear if and how monetary valuation of NBS can become more comprehensive or holistic, when the majority of published project assessments involve the quantification of just a handful of indicators.

Drawing on the wider literature around NBS and NBS-like interventions (see Figure 1), it is evident that many authors have reported the results of monetary valuation studies, covering diverse settings and interventions but all within the urban fabric itself. In this respect, our findings do not concur with those of Croci et al. (2021), who themselves confirm that their analysis was developed based on limited literature. Our results certainly do not indicate that there is a scarcity of economic valuations in the literature relating to urban ecosystem services (c.f. Croci et al., 2021).

This is not to say that improved frameworks are not required to support the valuation of natural and non-market goods and services; there is clearly a policy need (e.g. EC, 2022, proposals for a nature restoration law) for more effective economic valuation of the net benefits of nature-based investment (Ma, Henneberry & Privitera, 2021), especially in cities and notably for NBS interventions retrospectively fitted into the urban fabric.

5.2. Co-producing understanding of NBS impact indicators & valuations (focus groups with cities)

Discussions with the partners in the Conexus project and the cities' priorities for NBS highlighted the importance of NBS impacts within the categories of participatory planning and governance, social justice and social cohesion, and knowledge and social capacity building. In particular, themes relating to participation, governance, co-creation, social inclusion and social cohesion were viewed as centrally important alongside e.g. ecological and physical environmental impacts such as biodiversity and water quality (Figure 3).

Very few peer-reviewed articles in the literature report on research seeking to tackle the economic valuation of social, cultural and political outcomes or impacts of NBS. Notable exceptions include attempts to develop methods around socio-cultural valuation (Derkzen et al., 2017), combinations of qualitative and quantitative valuations (e.g. Neumann & Hack, 2022; Teotónio et al., 2022) and efforts to obtain in-depth knowledge of perceptions and beliefs to incorporate into valuations (Islam et al., 2019). These approaches appear close to the ambitions for a deliberative valuation paradigm to integrate various disciplines, tools and techniques to bridge inputs from citizens and academia (Raymond et al., 2014).

Here, the project approach involved focusing in on impact indicators that were central to the societal challenges actually being addressed within cities, through the involvement of participants directly involved in the development of those NBS propositions and initiatives. This reflects the transdisciplinary approach and partnership that is fundamental to the Conexus project.

The results summarising participants' perspectives as to the most relevant economic assessment techniques (Table 3) in each particular Conexus city highlight that there is value in seeking to understand relationships between those methods and specific societal challenges in play in those cities. A clear finding from the focus groups was that each of the six cities involved has ambitions to deliver a wide range of NBS co-benefits across the whole spectrum of indicators (all cases), and that some - but not all - of those impacts can be relevant in terms of monetary valuations.

This sense of economic assessments being just one useful tool in the toolset also forms a key strand of the results in our semi-structured interviews (see subsequent section). In the next steps of our project, economic valuations of NBS impacts will be pursued in some of the cities with the input of staff cooperating across the Conexus partnership in Latin America and Europe. The literature on monetary valuations applied in relation to NBS and NBS-like interventions has been used to support this process, through the filtering of publications according to impacts and economic valuation methodologies, and refinement of work plans.

5.3. Understanding how Conexus cities currently view monetary valuation of urban nature and NBS – including if and how economic assessments are being applied (semi structured interviews)

The results of one-to-one discussions with representatives of the city- and regional- governments has proven to be invaluable in providing a deeper understanding of both the contexts for, and approaches to economic assessment of NBS. An obvious result (Table 4) is that cities differ, not just in their political priorities and the societal challenges they face, but also in the state of the art as regards their use (and support for the notion of) monetary valuation in NBS decision-making. Our results appear to indicate some differences in Latin American compared with European cities' experiences in the application of economic assessments to supporting decision making around NBS. Although the project only involved a limited number of cities, Latin American cases seemed to have advanced further in their application of monetary valuation methods relating to NBS. This finding warrants further research; we could find no other relevant references on this topic.

An important finding is that city- and regional- government staff have a clear and nuanced understanding of the role of economic valuation alongside rather than instead of other 'value articulating institutions (Kallis et al., 2013). The results also indicate that economic evidence relating to NBS in cities and other urban greening interventions may have little importance, or may be applied post-hoc in support of decisions that were already in hand, or that monetary measures were rather peripheral when it comes to the ecological impacts of urban ecosystem restoration. The findings point to a sensitivity to the importance of non-use and existence values.

Furthermore, a critical aspect relating to the actual application (or otherwise) of monetary valuations relating to NBS involves the availability and quality of datasets, and capacities to apply those techniques ("it is a tool that not everyone knows how to use"). It is striking that this limitation applies even in some of the largest cities in the world and in those cities with a reputation as leaders in their field apropos their greening programmes and sustainability credentials. Whilst the field of natural capital accounting is perhaps advancing quickly, its impacts in the cities that we have studied have been limited, at least as far as NBS interventions within the urban fabric are concerned. Why might this be the case? An examination of the literature shows that whilst the application of economic valuations to urban NBS is reasonably commonplace in academic circles, these studies tend to be limited to particular types of interventions, using rather complex methodologies, demanding extensive datasets, and also usually tend to be limited to just a few impacts. It is worth noting that several of the ecosystem services assessments applied across multiple impact domains involved the use of benefit transfer models. Applying these techniques in urban areas, where land parcels and ownership is more fragmented and complex is likely to be more complicated and challenging than in rural areas, where remote sensing and GIS based approaches can be more readily assessed, due to greater homogeneity in land use patterns.

Key findings and conclusions drawing on the results of the semi-structured interviews, and the wider literature, were therefore that:

(1). Although economic valuation of benefits is still not widely applied in the process of decision making, results have a potential as an important communication tool to decision makers. This is especially important in communicating costs of adapting to climate change and biodiversity loss, and how costs of not adapting can be higher (Agrawala et al., 2008; Sanderson and O'Neill, 2020).
(2). Negative perceptions of monetarisation of nature might be mitigated by integrating the results with other forms of assessment, whereby other socio-ecological values are also included and valued by different stakeholders; attention must also be given to the risks of green gentrification (García-Lamarca et al., 2022; Toxopeus et al., 2020).
(3). Although public budgets for urban greening projects are increasing, and public-private financing might be an additional source for funding NBS initiatives (Seddon et al., 2020), little or no evidence was found in support of this occurring yet in the Conexus cities (see Dempsey and Suarez, 2016).

5.4. Overall impressions

However, our results also indicate that cities have the option to make significant progress in applying monetary valuations alongside other forms of impact assessment, in seeking to remove one of the most important barriers to producing robust NBS business cases in cities, which is to maintain a coherent, consistent and straightforward narrative for NBS implementation.

Judging by the literature and the findings from semi-structured interviews and focus groups, this can be achieved by basing arguments for NBS on less complex economic modelling of a more modest set of societal challenges. Cities have the option to use simpler messages that strongly resonate with citizens perspectives of their city, and the associated socio-political contexts for NBS. Doing so may also allow NBS proponents in cities to better handle the complexity of land use and ownership issues, and to develop NBS impact assessment frameworks with a manageable scope and span in terms of data demands.

In many respects, this conclusion relates to the need for improvements in the development of participatory frameworks for NBS impact assessment. Such advances in the interaction between governance and impact assessment may help with valuation and business case development.

Analysing the market for NBS, in terms of demand (buyers) and supply (sellers), can assist in better understanding barriers to adoption as well as strategies and instruments to overcome those challenges (Whiteoak 2020). We can seek to better understand the market for NBS in terms of the cities themselves as customers, and the NBS benefits that those cities want or need to 'buy'.

Case studies and stories of cities' investment in NBS programmes can serve to illustrate how a more targeted assessment of economic values of NBS can be both powerful and purposeful. However, which impacts to focus upon, and which indicators to apply, depends on the specific place considered. Establishing the economic case for NBS is important if local authorities and private enterprises are to continue to invest in urban greening (Wild et al., 2017), as is the need to balance social or ecological needs with economic viability (Mell et al., 2013).

Several different reasons exist for undertaking such economic analyses, and it is important to understand the contexts for the decisions to carry out such investigations. Such *decision contexts* can include (1) awareness-raising; (2) accounting; (3) priority-setting; (4) design; (5) calculation of economic liability; and (6) understanding development dynamics and economic viability (Barton 2015; Wild, Henneberry and Gill 2017).

Our findings indicate that valuation methods have been applied in relation to NBS, GI, urban forestry and other NBS-like interventions, but that valuation may be less commonly applied to support actual city decision-making processes, partially due to mismatches between those decision-making processes, NBS valuation methods, and standard accounting methods. Toxopeus & Polzin (2021) note that "there is a large variety of valuation strategies that does not yet allow for an integrated accounting and valuation framework for NBS". Greater knowledge exchange around successes and limitations in the application of these innovative methods is likely to prove fruitful in advancing the state of the art in urban NBS valuation, but only if city proponents for NBS are directly involved in that research and innovation process.

At present, three main approaches have gained ground in the assessment of NBS impacts: (1) the Eklipse framework (Raymond *et al.* 2017); (2) the IUCN Global Standard (Cohen Stracham *et al.* 2019); and (3) the EC's Impact Assessment Handbook (Dumitru and Wendling 2021). These frameworks agree on the need to support and enhance biodiversity and ecosystem integrity (Seddon *et al.* 2021); all stress the importance of co-designing NBS with citizens and stakeholders.

Furthermore, these frameworks share in common their comprehensiveness in terms of ecosystem services, the wide variety of benefits to be assessed, and their complex technical support requirements (e.g. IUCN offers training at cost and requires assessment of results by a panel of experts). The scope and span of an envisaged NBS programme or project in an urban area, according to these frameworks, could thus become hugely demanding of data. Other research in Conexus has found that thus far, the uptake of these frameworks by cities in Europe and Latin America is limited, and that such assessment frameworks tend to lack critical governance indicators (Van der Jagt *et al.* 2023; Kauark-Fontes et al., 2023). Furthermore, the three frameworks do not explicitly address scaling issues or specify detailed *decision-contexts* described above. These results echo earlier findings that overly complex tools and approaches to promote green economy are rarely applied in urban green space planning (Davies *et al.* 2015).

So where does this leave us? City authorities' evident lack of uptake of NBS assessment frameworks may indicate that they are overly complex, insufficiently connected with cities' cultural, ecological and social imaginaries, or too demanding of data (including extraneous or largely irrelevant data). In other words, perhaps current models for NBS impact assessment do not adequately address the societal challenges that cities face (or provide the tools to do so), nor the socio-political frameworks within which NBS actions are embedded. This potential disengagement also serves to highlight how the 'market' for NBS in terms of cities as their buyers and suppliers (Whiteoak 2020) might be better understood. Clues to this might also come from the more frequent uptake of sustainability appraisals and sustainability action planning (Van der Jagt *et al.* 2022; Salbitano *et al.* 2021).

Building on previous frameworks for integrated sustainability (Weaver and Rotmans 2006; Hurley *et al.* 2010), participatory assessment offers the scope of a cyclical process of scoping, via which a shared interpretation of sustainability is developed and applied in an integrated manner for a specific context (Wild *et al.* 2015). In other words, by involving local stakeholders directly in the process of defining which are the key criteria and indicators of success, this increases the chances of both monitoring and achieving those outcomes. When NBS assessment is more contextualised and based on wide stakeholder participation, it can generate more useful data (Van der Jagt *et al.* 2022), which are also more likely to be meaningful in terms of valuations.

Broad assessments of NBS impacts may be driven by the belief that project financing depends strongly on linkages between green urban infrastructure and other themes such as regional development, climate adaptation and so on (Merk *et al.* 2012) aligning partnership agendas to cross subsidise projects that would not otherwise be viable. However, it has been highlighted previously that this broad scope may also be one of the biggest weaknesses of NBS (Wild, Henneberry and Gill 2017), if propositions are not properly costed, accounting for core benefits and can be dismissed as 'jack of all trades, master of none'.

6. CONCLUSIONS AND RECOMMENDATIONS

Urban municipal and regional authorities face multiple challenges, some of which can be addressed using NBS. The multifunctionality of urban NBS represents their key strength but also means that proving their impact in terms of cost-effectiveness can quickly become complex and onerous. Large amounts of data exist on NBS performance for certain solutions, such as sustainable drainage and urban forestry, but these benefits are often context-specific, and the data may not be readily transferable. Steadily, NBS impact assessment guidance frameworks are becoming more readily available. However, the most widely known and accepted frameworks to assess NBS services and disservices tend to promote holistic and comprehensive analyses, requiring extensive datasets and expertise. Onerous or demanding assessment frameworks may be less frequently applied in cities, where land use information is more complex and fragmented than in rural environments.

Participatory assessment frameworks in which stakeholders (such as urban municipal authorities) are responsible for driving the decision-making around which indicators to develop and apply may offer a more productive approach, by bringing NBS assessments closer to local socio-political priorities within cities, and enabling better (access to) data on urban challenges and NBS performance. The number of publications on NBS is increasing exponentially (Wild, Freitas and Vandewoestijne eds. 2020) and a significant proportion of these studies address the economic valuation of urban NBS, representing a strengthening evidence base to underpin NBS business case development. Indeed, many of these publications stem from studies in Latin America. We highlight invaluable case studies and signposts to further information, to support the work of stakeholders seeking to improve urban NBS business case development.

Bearing in mind the above, certain key recommendations can be made. Firstly, NBS assessments can be narrow or wide in both their span in terms of benefits and their scale geographically. Data demands increase exponentially where both the substance and scale of the assessment are widened. This means that assessments of broad environmental, social and economic outcomes at the city scale are likely to require such extensive data gathering as to become impractical, or to build in so many assumptions that they are unlikely to be convincing or can be readily unpicked.

Secondly, NBS themselves and the metrics used to ascertain or predict their benefits can be, and should be, closely matched with their city contexts. Most city strategies and plans give strong indications of the most relevant challenges and the NBS propositions should probably address these criteria.

Thirdly, stakeholder participation is critical not only in the co-design of planned NBS, but also in the co-designing the measures of success. Whilst examples of this are rare, tools do exist to support the creation of participatory assessment frameworks in cities.

7. ACKNOWLEDGEMENTS

This research was funded by the European Commission's Horizon 2020 research and innovation programme through the CONEXUS project, under Grant Agreement no. 867564. We would like to thank the participants and partners in the project, including Livia Marchetti for her support with translation of the Italian transcripts, and anonymous reviewers for their help in improving this report.

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ANNEXES

Annex 1. List of questions for semi-structured interviews with local municipality and regional government staff in the Conexus cities (regarding monetary valuation of NBS programmes and projects)

About the interviewee

- Please can you tell me a bit about your background and professional interests?
- Which department do you work in?
- What is your job position within the institution and how did you get to this position?
- How long have you worked in this position?

About their role

- What are your responsibilities at work? Could you please tell me about a typical day at work?
- How are you involved in decision-making for green space planning, management and investment?
- Do you develop options and recommendations for decision-makers? If so, what processes do you use to support their decisions? If not, do you know the person responsible for this 'in your authority' or in other partner organisations?

About their experience with economic valuation

- What do you think about economic valuation? And applied to greening? And applied to restoration of nature in cities?
- What, if any, kinds of funding sources do you access for projects that involve the restoration of nature in cities? e.g do you have access to international/national funding.
- Do funders ask for economic valuation of benefits? e.g cost-benefit analysis?
- If so, how is your experience with economic valuation? What valuation techniques do you use? What are the benefits that are valued? Which are the core indicators that underpin this valuation?
- If not, what are the barriers?
- If your city does not have access to funding for urban nature restoration projects, are there other sources of funding available to other type of projects? Do those involve monetary valuation?

Alternative questions:

- When do you use valuation techniques?
- Please describe if you can an example of when you use valuation techniques to support decision making?

Closing

- Is there anything else you would like to add that we have not covered in our conversation?