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Knowledge & Learning Mechanism
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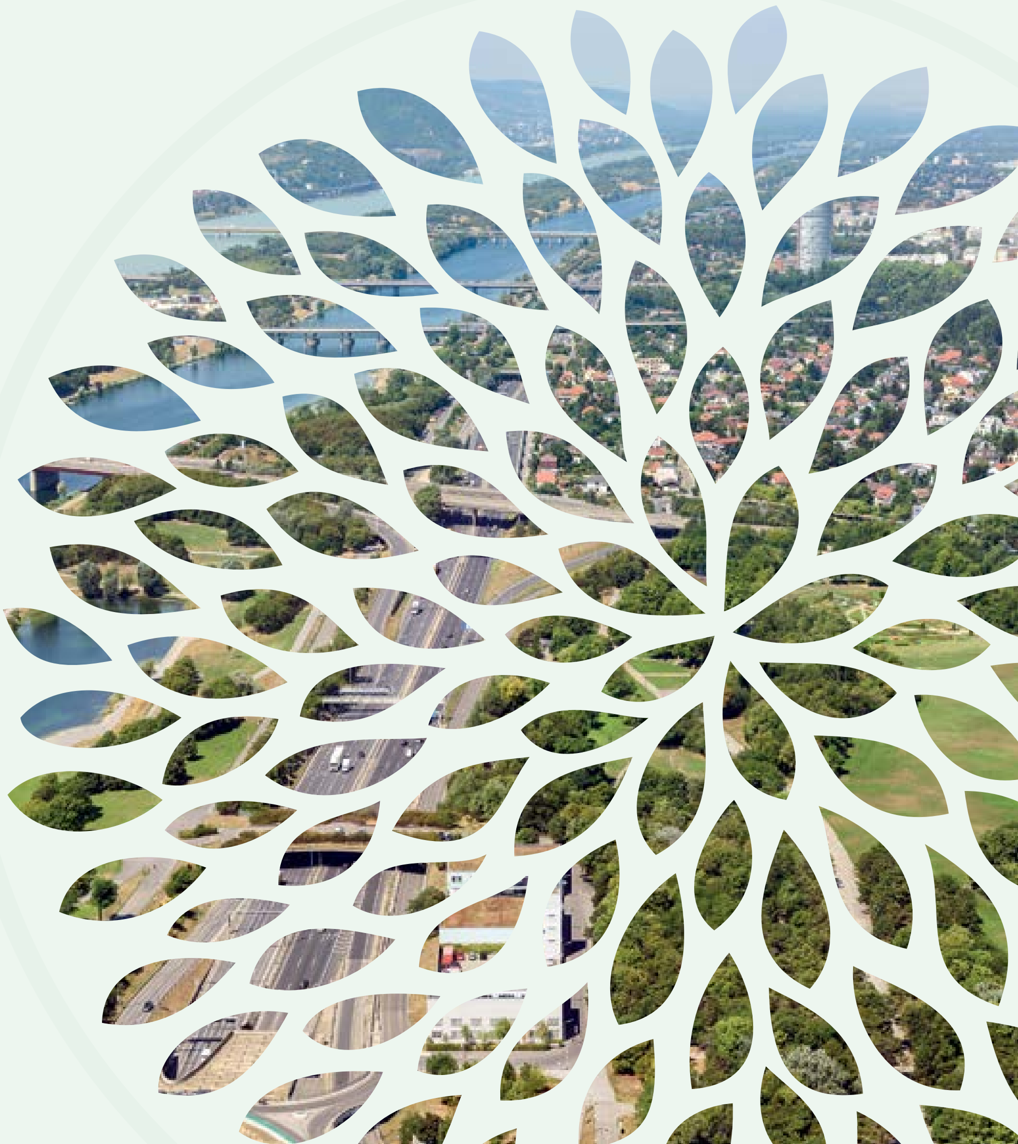
An impact evaluation framework to support planning and evaluation of nature-based solutions projects

An EKLIPSE Expert Working Group report



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An impact evaluation framework to support planning and evaluation of nature-based solutions projects

An EKLIPSE Expert Working Group report

Prepared by the EKLIPSE Expert Working Group on Nature-based Solutions to Promote Climate Resilience in Urban Areas

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This document reflects the results of a quick scoping review of the peer-reviewed and grey literature and is not intended to be comprehensive. It explores the multiple dimensions of impact that nature-based solutions projects may have when implemented at different scales, from building to regional. To meet this objective, an impact assessment framework was formulated, which is intended to be used to guide an assessment of the effectiveness of nature-based solutions projects. It is the first step in the process, and is likely to be refined by other expert working groups in 2017.

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Glossary of Key Terms

Term	Definition	Key references
Adaptation	An adjustment in ecological, social or economic systems in response to observed or expected changes in climatic stimuli and their effects and impacts in order to alleviate adverse impacts of change or take advantage of new opportunities.	Adger et al. (2005)
Carbon storage	The amount of carbon stored in biomass (leaves, stems, trunk, roots and soil organic matter).	Nowak et al. (2008)
Carbon sequestration	The process of increasing the carbon content of a reservoir or pool other than the atmosphere (e.g. biosphere, oceans).	Adapted from IPCC (2007)
Climate mitigation potential	The potential of reducing GHG emissions (in particular carbon emissions) through the implementation of NBS at different spatial scales, thus contributing to the global challenge of reducing climate change.	Adapted from IPCC (2014)
Co-benefits	The various benefits that can be provided by a NBS simultaneously over a certain period.	Jiang et al. (2016)
Cost-benefit analysis	The process of quantifying the costs and benefits of a NBS (over a certain period), and those of its alternatives (within the same period), in order to have a single scale of comparison for unbiased evaluation.	Adapted from Atkinson and Mourato (2015)
Economic cost	The cost of designing and implementing NBS over a certain period. It may include acquisition, management, transaction, damage and opportunity costs.	Naidoo et al. (2006)
Economic benefit	The economic advantages of designing and implementing a NBS over a certain period, quantifiable in terms of monetised costs and benefits, including generated cash flows.	
Economic opportunity	When a supplier of a NBS service or good succeeds in providing this through a market mechanism to a consumer for an added value.	
Ecosystem services	The contributions of ecosystem structure and function, in combination with other inputs, to human well-being.	Burkhard et al. (2012)
Ecosystem disservices	Negative contributions of ecosystems to human well-being, including undesired and harmful impacts on the environment, that relate to the generation of ecosystem services.	Potschin et al. (2016) Von Döhren and Haase (2015)
Evapotranspiration	The combined process of evaporation from the Earth's surface and transpiration from vegetation.	IPCC (2012)
Green space	Urban green space is land within urban areas that is partly or totally covered by vegetation. The term can be applied to existing or planned green elements and structures for all kinds of urban green (and blue) spaces regardless of their ownership, management, current use, and functionality. This includes parks and street trees, as well as urban agricultural and forest land, wastelands, cemeteries and private gardens (including roof gardens).	Breuste et al. (2013); Davies et al. (2015)
Heat island effect	Closed isotherms indicating an area of the surface that is relatively warm; most commonly associated with areas of human disturbance, such as towns and cities. The physiographic analogy derives from the similarity between the pattern of isotherms and height contours of an island on a topographic map. Heat islands commonly also possess "cliffs" at the urban–rural fringe and a "peak" in the most built-up core of the city. The annual mean temperature of a large city may be 1°–2°C warmer than before development	Glossary of Meteorology, 2012

	and on individual calm, clear nights may be up to 12°C warmer.	
Impact	The effect of a NBS in achieving a specified objective and/or dealing with an urban challenge; evidenced as a change in environmental, social, economic and ecological conditions and functions.	
Macro-, meso- and micro-scale	From an ecological perspective, the macroscale corresponds to the global-biome level, the mesoscale aligns with the landscape/ecosystem scale and the microscale coincides with the scales ranging from ecosystems to individual organisms. From an institutional perspective, the macroscale corresponds to the global and international level, the mesoscale represents the regional through to metropolitan and urban scales, and the microscale coincides with the scales ranging from the neighbourhood and street to the single building.	Following Hein et al. (2006)
NBS Effectiveness	The degree to which objectives are achieved and the extent to which targeted problems are solved. In contrast to efficiency, effectiveness is determined without reference to costs. E.g., • Does the NBS lead to enhanced climate resilience in the urban area? • Does the NBS lead to environmental benefits? • Does the NBS lead to social benefits? • Does the NBS lead to economic benefits?	Adapted from Oxford Dictionary (2016)
Performance	The degree to which NBS address an identified challenge (e.g., climate resilience) and/or fulfil a specified objective in a specific place (territory), time and socio-economic context.	Adapted from Dunn (2004)
Relevance	The degree to which a NBS contributes to dealing with the primary problem (performance).	
Reliability	The ability of a method to produce consistent results.	
Reliable NBS	A NBS whose performance is guaranteed over time with a certain defined maintenance strategy.	
Resilience	The capacity of a system to absorb disturbance and reorganize while undergoing change so as to retain essentially the same function, structure, identity, and feedbacks.	Walker et al. (2004)
Robustness	The capacity of an analytic procedure to remain unaffected by small, but deliberate variations in parameters.	
Robust NBS	A NBS that achieves the expected objectives and solves the targeted problem under different uncertain future situations.	
Social benefit	The range of ways in which individuals and societies can socially be positively impacted by NBS.	
Social cost	The range of ways in which individuals and societies can socially be negatively impacted by a NBS.	
Synergy in the delivery of ecosystem services	Synergy arises when increased provision of one ecosystem service causes improvement in the provision of another ecosystem service.	Potschin et al. (2016) Beumer et al. (2014)
Trade-offs	Situations in which one ecosystem service increases and another one decreases. This may be due to simultaneous response to the same driver or due to true interactions among services.	Potschin et al. (2016); Bardosa et al., 2016)

Report Summary

Nature-Based Solutions (NBS) are solutions to societal challenges that are inspired and supported by nature. The European Commission requested the EKLIPSE project to help building up an evidence and knowledge base on the benefits and challenges of applying NBS. In response to the request, the EKLIPSE Expert Working Group on Nature-based Solutions to Promote Climate Resilience in Urban Areas (EWG) devised the following objectives:

1) To develop an impact evaluation framework with a list of criteria for assessing the performance of NBS in dealing with challenges related to climate resilience in urban areas;
2) To prepare an application guide for measuring how NBS projects fare against the identified indicators in delivering multiple environmental, economic and societal benefits;
3) To make recommendations to improve the assessment of the effectiveness of NBS projects, including the identification of knowledge gaps according to the criteria presented in the impact evaluation framework.

This document reports on these three objectives. It is intended to be used as a reference document by members of current and future European projects with an interest in NBS in urban areas, and by practitioners seeking to compare the effectiveness of NBS design, implementation and evaluation. The EWG recognises that the type and intensity of NBS impacts may vary according to the characteristics of the NBS and the context in which they are applied. The intent of this report is not to define NBS, but rather provide examples of indicators and methods for assessing impacts of NBS that may be applied in a range of different ways across urban areas in Europe. As such, the report also identifies the scale at which the indicators are relevant, to guide an assessment of impacts.

In relation to objective 1, the EWG developed a framework that enables the assessment of impacts related to specific NBS actions within and across 10 challenge areas (Figures 2 and 3). The framework was based on a quick scoping review of the literature (Collins et al., 2015; Dicks et al., 2014) combined with expert consultation within and outside the EWG. Building on the mapping and assessment of ecosystems and their services (MAES, European Commission, 2013), it reflects the potential for the co-production of ecosystem services across climate, ecosystems, socio-economic and socio-cultural systems. It recognizes that NBS impacts vary across geographic and temporal scales. For this reason, it underlines the importance of defining critical thresholds for impacts at the local level. Furthermore, the report illustrates the potential for interconnections between climate change at the macroscale and mesoscale, and microscale interactions between the climate resilience challenges of climate mitigation and adaptation, water management, coastal resilience, air quality, green space management, urban regeneration, social justice and social cohesion, public health and well-being and economic opportunities and green jobs.

For each challenge area, the EWG presents a small number of representative examples of indicators that are considered to be important for assessing key impacts of specific NBS actions, as well as a range of methods for assessing each indicator. All challenges consider impacts at the mesoscale (regional, metropolitan, urban) and microscale (neighbourhood/street, building).

The report also describes some success factors and limiting factors (including synergies and trade-offs) and elucidates them with the aid of a case example. Tables 24 and 25 provide an indicative overview on the variety of indicators, methods and scales for assessment as well as possible dimensions to be measured across the different challenges considered. This framework does not provide a single answer for the assessment of NBS impacts. Rather, it recognises the potential for NBS impacts to vary across social and

ecological contexts, and across temporal and geographical scales. The identified indicators are exemplary and not exhaustive, and researchers and practitioners interested in NBS projects in cities are invited to enrich the impact assessment framework with additional operational and context-specific metrics and methods for valuation and assessment.

The cross-sector character of the impacts to be addressed in the assessment of NBS means that a range of different quantitative and qualitative indicators need to be considered. Methods based on multi-criteria assessment are thus often useful for aggregating different types of indicators in order to assess alternative solutions.

By compiling potential impacts across different challenge areas this report provides an important starting point for future projects to agree on a common assessment framework which will make experiences of applying NBS comparable across different research and application projects. Only by ensuring a minimum level of comparability will it be possible to build an evidence base on benefits, co-benefits, synergies and trade-offs of different NBS applications.

In relation to objective 2, a NBS application guide is presented that synthesises conclusions across all ten challenges. It is recommended that once the over-arching aim of a NBS project has been established, decisions are made about:

1) How each challenge could be addressed;
2) Which components of each challenge are relevant and will be addressed;
3) The geographical and temporal scale of the action and its effect;
4) Which indicator(s) will be appropriate to measure the effectiveness of individual actions in addressing each challenge;
5) Which methods are available, suitable and feasible for the measurement of the indicators;
6) What baseline will be used, including measurements that should be taken prior to the commencement of any action, so that effectiveness can be measured;
7) How to identify interactions between actions, and how to capitalise on the opportunities presented by co-benefits and tackle any trade-offs between conflicting desired effects.

This report concludes by providing a roadmap for the assessment of NBS impacts (objective 3), including a summary of knowledge gaps and associated future research and practice directions. While substantial attention has been directed towards assessing the environmental impacts of NBS, greater attention needs to be paid to both exploring and explaining the interlinkages between environmental, economic and social impacts within and across the 10 climate resilience challenges, and across different geographic and temporal scales. Such advancements will require a commitment to interdisciplinary research and practice that draws upon a range of indicators and qualitative, quantitative and mixed-methods techniques for assessing them. Multi-stakeholder networks on NBS design, planning and implementation will be important to ensure the transference of successful approaches from one country to another, or from one case study to a wider community. Moreover, the successful implementation of NBS will require a commitment to the monitoring and evaluation of NBS beyond the urban context and across urban-rural gradients using innovative participatory planning and governance processes which actively engage multiple types and systems of knowledge, and translate the benefits of NBS in ways that motivate action by urban residents, not solely planning authorities. For these reasons, the authors strongly encourage researchers and practitioners to move from the assessment and valuation of ecosystem services to a wider assessment of the co-benefits (and costs) of NBS through the lens of co-production of ecosystem services. Hopefully the guidance provided in this report will assist with such ambition.

Background

Nature-Based Solutions (NBS) are solutions to societal challenges that are inspired and supported by nature, which are cost-effective, provide simultaneous environmental, social and economic benefits, and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions (European Commission, 2016), and thus they simultaneously provide benefits for biodiversity and human well-being (Cohen-Shacham et al., 2016).

Under Horizon 2020, NBS have been identified as a priority area for investment. For example, funding area SCC-02-2016-2017 supports demonstration projects on NBS for climate and water resilience in cities (2016) and NBS for inclusive urban regeneration (2017); and SC5-8-2017 supports large-scale demonstrators on NBS for hydro-meteorological risk reduction. Four NBS demonstration projects, in excess of 10 million Euros each, have been selected for funding for climate and water resilience in cities (SCC-02-2016). The purpose of these projects is to enhance resilience in urban areas in the face of climate change impacts such as temperature extremes, pollution, wind, drought and flooding, using nature-based solutions.

Recent studies have provided perspectives on indicators, knowledge gaps, barriers and opportunities for action on NBS (Kabisch et al., 2016; Nesshöver et al., 2016), but to date a holistic framework has not been developed for the assessment of NBS impacts across a range of climate resilience challenges at different geographic scales. The European Commission Director General, Research and Innovation (EC DG R&I) therefore requested the EKLIPSE project to provide a framework for NBS projects so that a common evidence and knowledge base for NBS can be built in the future. In response, EKLIPSE issued a call for experts (No.1/2016) to develop an impact evaluation framework to guide the design, development, implementation and assessment of NBS demonstration projects in urban contexts (EKLIPSE, 2016). Fifteen experts were selected by EKLIPSE to address the request, forming the EKLIPSE Expert Working Group on Nature-based Solutions to Promote Climate Resilience in Urban Areas (EWG). The experts came from both science and practice and represented a range of areas including ecology, air quality and climate science, ecosystem governance, environmental psychology, human geography, land-use design and urban planning, environmental economics and water management.

Aims and objectives

The aim of this EKLIPSE activity is to devise an impact evaluation framework that can guide the design, development, implementation and assessment of NBS demonstration projects in urban contexts. The framework needs to take into account insights from recent studies into the mapping and assessment of ecosystems and their services, ecosystem-based adaptation projects, and relevant information on climate adaptation, natural water retention, green infrastructure, greening cities and other European Commission-based initiatives (EKLIPSE, 2016).

In response to the request, the EWG devised the following objectives:

1) To develop an impact evaluation framework with a list of criteria for assessing the performance of NBS in dealing with challenges related to climate resilience in urban areas;
2) To prepare an application guide for measuring how NBS projects fare against the identified indicators in delivering multiple environmental, economic and societal benefits;
3) To make recommendations to improve assessment of the effectiveness of NBS projects, including the identification of knowledge gaps according to the criteria presented in the impact evaluation framework. These recommendations are included in the application guide.

It is important to note that the results of these activities present an initial set of indicators and assessment methods that are recommended in the literature on the assessment of NBS impacts. The study focuses on the assessment of NBS to support climate resilience in urban areas, but did not consider the applicability of NBS for disaster reduction. The impact assessment framework presented here will be adapted in the future when projects begin to apply it. The Think Nature NBS Platform, recently supported under Horizon 2020, may also play an important co-ordinating role in this refinement process.

Methodological Approach

The EWG methodological approach involved a quick scoping review of the literature combined with expert consultation within and outside the EWG. The EWG selected 10 challenges from the expert report on NBS supported by DG Research and Innovation (European Commission, 2016) and a recent review of NBS frameworks (Kabisch et al., 2016):

1) Climate mitigation and adaptation;
2) Water management;
3) Coastal resilience;
4) Green space management (including enhancing/conserving urban biodiversity);
5) Air/ambient quality;
6) Urban regeneration;
7) Participatory planning and governance;
8) Social justice and social cohesion;
9) Public health and well-being;
10) Potential for new economic opportunities and green jobs.

It was deemed by the EWG that NBS targeted at addressing each of the 10 challenges would also support climate resilience in urban areas. Further, it was deemed that different climate mitigation and adaptation responses can be undertaken at each of the three scales: macroscale, mesoscale and microscale. From an ecological perspective, the macroscale corresponds to the global-biome level, the mesoscale aligns with the landscape–ecosystem scale and the microscale coincides with the scales ranging from ecosystems to individual organisms. From an institutional perspective, the macroscale corresponds to the global and international level, the mesoscale represents the regional through to metropolitan and urban scales, and the microscale coincides with the scales ranging from the neighbourhood and street to the single building (following Hein et al., 2006). While there is a range of climate mitigation and adaption options at the macroscale, this report focuses on NBS at the mesoscale and microscale. Consequently, the EWG used its expert judgement and the literature as a guide to assess the applicability of impact indicators at regional, urban, metropolitan, street/neighbourhood and building scales.

The quick scoping review of the literature adapts procedures and insights from a rapid evidence assessment methodology used in the conservation sciences (Collins et al., 2015; Dicks et al., 2014). The scoping consisted of three stages (Figure 1). Stage one involved a structured search of the scientific and grey literature. Stage two involved asking EWG members and EU project co-ordinators involved in projects related to NBS to add to the body of literature by suggesting up to 10 important papers per challenge area based on their area(s) of expertise. Stage three involved a narrative synthesis of the selected scientific and 'grey' literature. Due to time and resource constraints, stage three was modified during the project to focus on an initial set of examples of the most important indicators and methods for assessing the impacts of NBS as identified by the expert working group members, as opposed to a representative set of indicators and methods. The Protocol document provides further information about the methodological approach (Raymond et al., 2016a).

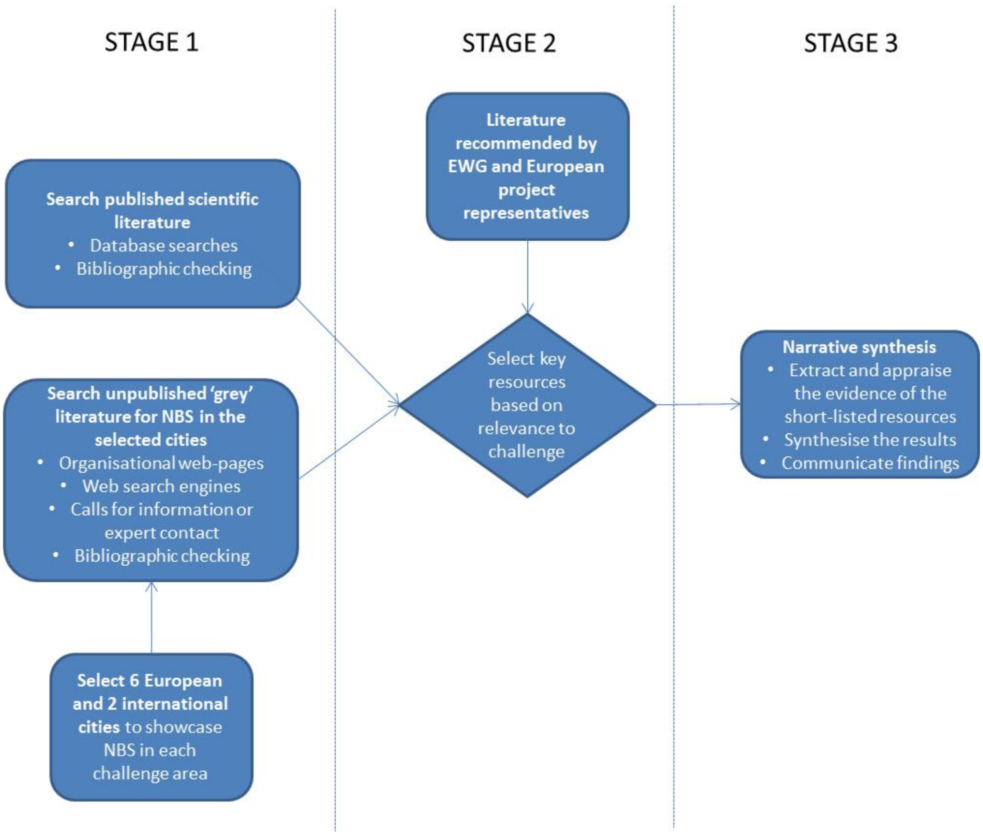

Figure 1 The three stages of the quick scoping review of the literature.

Short overview of the literature considered in the scoping exercise

Table 1 presents a short overview of the quantity of the literature considered in the scoping exercise. Only relevant literature was included in the description of the initial set of indicators. Relevance was determined based on the degree to which the paper included content relevant to the search strategy criteria presented in the protocol document (Raymond et al. 2016a).

Table 1 Literature considered in stages 1 and 2

Stage 1	Stage 2
• 320 peer-reviewed articles or books all read to at least abstract level • 1223 pieces of grey literature • Grey-literature further screened based on titles, 10% read to at least summary level	• 247 unique articles, books or reports not identified in Stage 1 all read to at least abstract or summary level

NBS Impact Assessment Framework

The NBS impact assessment framework (Figures 2 and 3) builds on and supports several other closely related concepts, including the ecosystem approach, ecosystem-based adaptation and mitigation, green and blue infrastructure and ecosystem services (European Commission, 2015). The European Commission, through MAES (Mapping and Assessment of Ecosystems and their Services), is assisting Member States in the process of mapping and assessment of ecosystems and their services, as well as assessing the economic value of such services, and incorporating these values into EU and national accounting and reporting systems (European Commission, 2013). This is in order to operationalize and meet Target 2, Action 5 of the

EU Biodiversity Strategy to 2020 and to contribute to the Europe 2020 strategy to build smart, sustainable and inclusive growth for the EU.

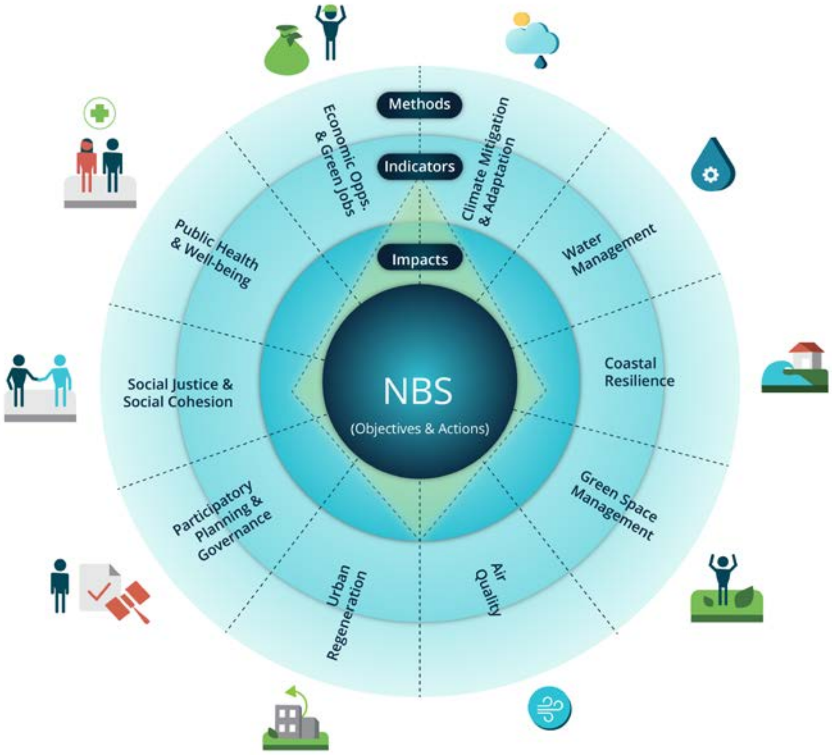

Figure 2 The 10 climate resilience challenges considered in this impact assessment framework.

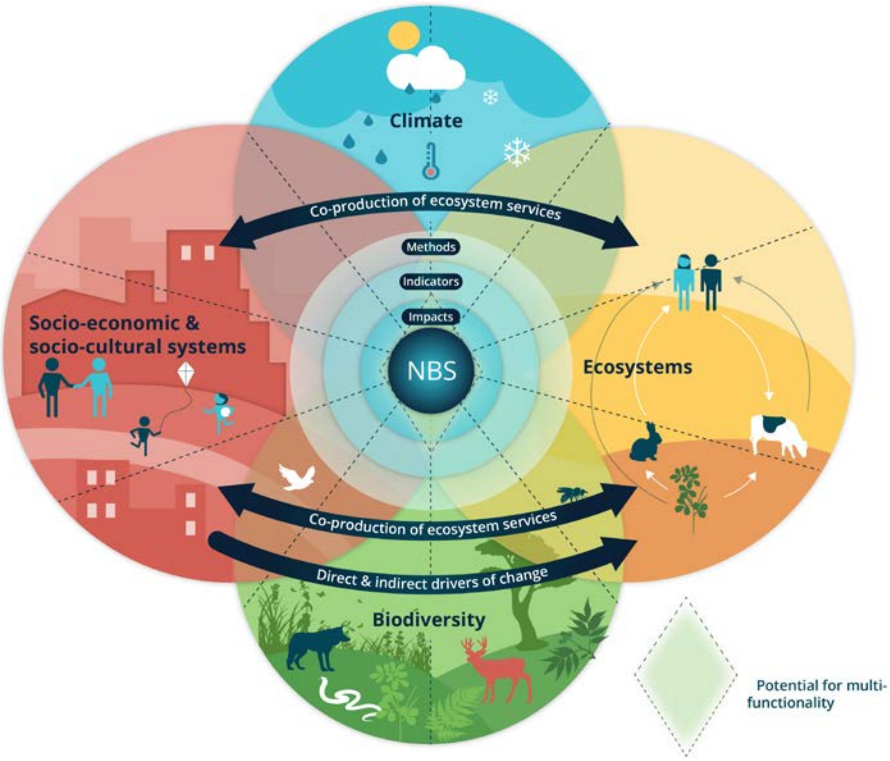

Figure 3 Framework illustrating the relationships among elements of biophysical and social systems, climate resilience challenges and the NBS actions, impacts, indicators and methods for addressing each challenge.

A NBS directed towards a given challenge has an associated set of objectives and actions. Each action has an associated set of expected impacts, and these impacts can in turn be assessed using a set of indicators, using specific types of methods for assessing those indicators (Figure 2).

The focus of this study is on the use of NBS to enhance climate resilience in urban areas in the face of climate change impacts such as extremes of temperature, wind, drought and flooding, while also producing climate change and pollution mitigation benefits. However, it is recognised that due to their multi-functionality (their capacity to perform different functions and present a range of benefits simultaneously and over time) any NBS is likely to have co-benefits (and costs) in other challenge areas and to benefit biodiversity (Kabisch et al., 2016). The classification presented here has been designed specifically for the purpose of this document, but it is acknowledged that each of the 10 challenge areas can be expanded or reduced to consider all the multi-functional aspects of NBS. There is potential for indicators and methods to be applicable to more than one challenge area, as illustrated by the diamond body in Figures 2 and 3. In the application guide of this report, we discuss the applicability of indicators and methods across challenges.

It is also important to consider the socio-ecological context in which NBS are embedded. Traditional ecosystem service assessments, such as the MAES framework, mainly focus on the linkages between stocks and flows of ecosystem services and their benefit to humans (as expressed through biophysical or monetary values), whereas the present NBS impact assessment framework recognises the potential for a range of other social, economic and environmental impacts. This broader view is reflected in the conceptualisation of the co-production of ecosystem services among and across climate, ecosystems, socio-economic systems and socio-cultural systems (Figure 3). Co-production can take on multiple forms:

1) Processes for combining multiple forms of knowledge and evidence to guide ecosystem management (Guerry et al., 2015; Reyers et al., 2015; Tengö et al., 2014);
2) The combination of different forms of natural, human, financial and manufactured capital to obtain ecosystem services (Biggs et al., 2015; Palomo et al., 2016);
3) The complex interactions between the socio-cultural systems (e.g., traditions, philosophy, ethics; world views, values, attitudes and beliefs; behaviour and lifestyles) (Flint et al., 2013) and other direct and indirect drivers to affect the state and condition of ecosystems (Huntsinger and Oviedo, 2014; Plieninger et al., 2015; Raymond et al., 2016b; Setten et al., 2012). Socio-cultural interactions with the ecosystem often give rise to non-monetary values which can be relational, instrumental or intrinsic (Chan et al., 2012, 2016);
4) The interactions between individuals and groups which guide shared values, beliefs and actions. When considered in a group context or when statistically aggregated, it is possible to identify shared, social and plural values (Kenter et al., 2015; Raymond et al., 2014);
5) The complex interactions between socio-economic systems (including markets, policy instruments, institutions and governance systems) and other direct and indirect drivers affect ecosystems.

The arrows in Figure 3 are not intended to represent causal or explanatory pathways, but rather to conceptually represent the complex interrelationships among aspects of the socio-economic and socio-cultural systems, ecosystems, biodiversity and climate. Figure 3 also shows that this report only addresses some of the many potential impacts that NBS are likely to have on aspects of the wider system.

From an assessment perspective, there are important similarities and differences between the NBS Impact Assessment Framework and MAES (Figure 4). Like the MAES framework, the NBS framework links ecosystems to socio-economic systems via the flow of ecosystem services and their benefits, and through the drivers of change that affect ecosystems either as consequence of using the services or as indirect impacts due to human activities. It separates elements of the socio-economic and socio-cultural systems to emphasise the need for integrated assessments, and underlines the importance of both monetary and non-monetary valuation techniques to the assessment of NBS impacts. Both MAES and the NBS framework use indicators. In MAES these are for establishing the link between biodiversity, ecosystems and the services they provide, and as a means of assessing ecosystem service delivery, and a number of these are relevant to NBS. In the NBS framework, indicators have been selected to demonstrate the effectiveness of different NBS actions for dealing with identified challenges. Indeed, there are a plethora of NBS and related impacts, indicators and methods related to climate change resilience in urban areas, as illustrated by the web of relations between NBS and the climate, ecosystems, socio-economic and socio-cultural systems. Here we focus on a subset of NBS, their impacts, indicators for assessing the impacts, and methods for assessing the effectiveness of NBS for a specific set of challenges, as represented by the blue target area in the middle of Figure 2.

Furthermore, differences exist in how relationships are identified and assessed in each framework. In the NBS impact assessment framework, researchers and practitioners place emphasis on the relationships between NBS, ecosystem services, co-benefits and diverse forms of impacts at different scales, and the processes used to engage multiple forms and systems of knowledge. The MAES framework places more emphasis on assessing biodiversity and the conditions of ecosystems in relation to their service provision (European Commission, 2013; 2014). In Figure 4 similar steps in the assessment process are represented with similar colours.

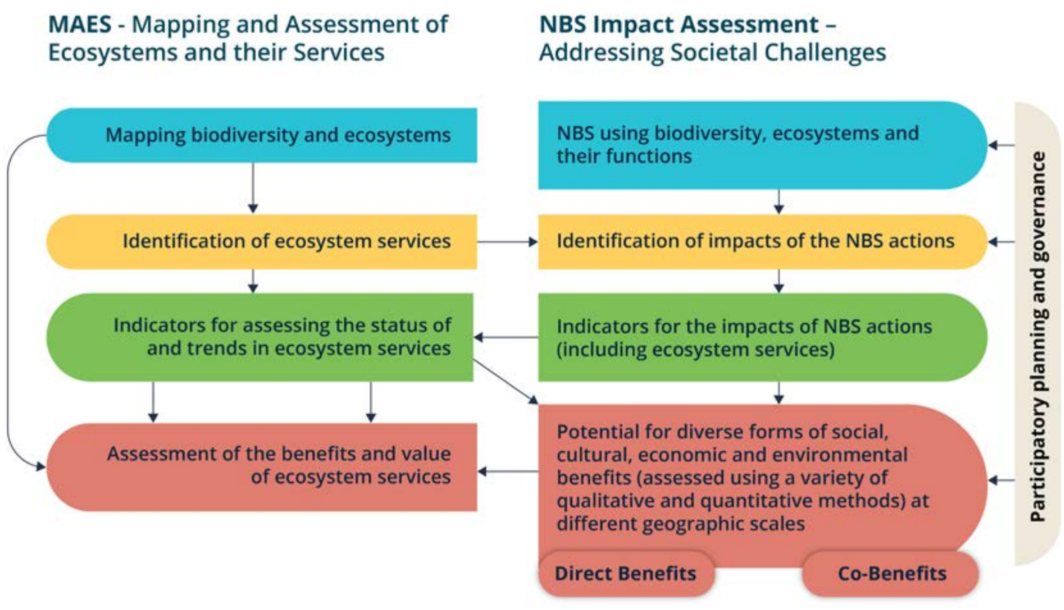

Figure 4 Flow diagram showing the relationships between the NBS impact assessment framework and MAES

Challenge 1: Contribution of NBS to Climate Resilience

The quality of life in European cities and in most of the world is threatened by a number of factors. The drivers include increasing pollution levels, urban heat islands, flooding and extreme events related to climate change, as well as decreased biodiversity (Grimm et al., 2008). These can have detrimental effects for human health and well-being. At the same time, cities are a large source of carbon emissions. The importance of action on carbon mitigation and greenhouse gas control at the urban level was addressed at the COP21 in Paris, highlighting that as the world becomes more urbanized, local action is becoming increasingly important (UNFCCC, 2016). For example, the European Commission's Covenant of Mayors (www.covenantofmayors.eu) obliges European cities to establish an Action Plan to reduce their carbon emissions by over 20%, including by using NBS and through the sustainable management of green space. Each city will need to aim for carbon-neutral urban development.

Climate resilience is based on two interacting concepts: "adaptation", that is the capacity to react and respond to an external stimulus or stress such as climate change, and "mitigation", that is the potential of improving the current status of a parameter or driver through active or passive behaviour, in this case through reducing greenhouse gas emissions or sequestering carbon. In the case of NBS, which involve elements of ecosystems, the two concepts are closely linked as any adaptation of an ecosystem can further influence the mitigation potential (e.g. by sequestering carbon in vegetation), with an overall dramatic effect on climate resilience (Calfapietra et al., 2015; Van Vuuren et al., 2011).

One of the major issues in implementing NBS for urban climate resilience and in understanding their potential impact and effectiveness is related to the scale of intervention. Action on climate mitigation can span the micro level of a single building, the meso level of the whole city or country and the macro level of the entire planet, though it has essentially a macro (global) scale effect through affecting global concentrations of greenhouse gases. Climate adaptation is more often planned and implemented at the meso (national) to micro (local) level, and the impacts are also at these levels. There are some common actions and indicators, but also some that are specific to the different scales of climate action to be addressed, as identified below.

This chapter gives an overview of the use of NBS for climate mitigation and for climate adaptation through regulation of the microclimate. Challenges 2 to 10 then provide more detail on the other ways in which NBS can contribute to climate adaptation, such as through improved water management and coastal resilience. Each of these chapters lists possible NBS actions, expected impacts, and examples of indicators and methods to assess those impacts. This chapter considers all scales from global to local, but the focus for Challenges 2 to 10 is on the meso and microscales of Regional, Metropolitan, Urban, Neighbourhood/Street and Building. Each of these chapters also reports a successful case study example of each approach, at least at a pilot scale.

Potential actions and expected impacts

NBS actions for climate resilience can be aimed at macro-scale mitigation, by enhancing carbon storage and sequestration in vegetation or soil and thus reducing global greenhouse gas concentrations (Table 2), or at meso and microscale adaptation through planting vegetation to improve the local or regional micro-climate through cooling, shading and shelter (Table 3). Many actions can achieve both of these impacts, so there is overlap between the tables.

Table 2 Potential actions for global climate mitigation and expected impacts

Potential actions	Expected impacts
• Increasing the area of (or avoiding the loss of) green space, particularly wetlands and tree cover, for both direct and indirect carbon storage.	• Carbon sequestration in vegetation and soil (Davies et al., 2011; Pataki et al., 2006). • Reducing the temperature at meso or microscales, thus decreasing the energy demand for cooling, especially in warmer climates, and reducing associated carbon emissions (Akbari, 2002). • Increased flood regulation (meso or microscale impact) (Pregnolato et al., 2016).
• Maximizing the net sequestration of carbon through species selection and management practices i.e. improving mitigation as well as choosing species that are adapted to future conditions.	• Climate change mitigation and carbon storage by vegetation, including carbon stored in soil (Davies et al., 2011; Pataki et al., 2006). • Improved air quality (mesoscale impact) (Baró et al., 2014).

Table 3 Potential climate adaptation actions at the meso and microscale and expected impacts

Potential actions	Expected impacts
• Increasing the area of (or avoiding the loss of) vegetation and particularly tree cover. • Increasing green walls and roofs to cool down the city through outdoor energy management using shading and the latent heat of evapotranspiration of plants and soils.	• Maximize cooling effect by evapotranspiration and shading, thus reducing local temperatures and ameliorating heat island effects and heat stress (Alexandri and Jones, 2008; Fioretti et al., 2010; Kazmierczak, 2012). • Securing long-term carbon storage in vegetation and soil and avoid carbon emissions from land-use changes (global impact). • Increased energy savings at building and street level through the insulating effect of plants (Alexandri and Jones, 2008; Zinzi and Agnoli, 2011). • Reducing wind speed and thus wind chill in cold climates.

Examples of indicators

Table 4 Examples of indicators for assessing the impact of climate mitigation actions at the macroscale

Indicators	Metric
• Carbon storage and sequestration in vegetation and soil (Davies et al., 2011; Demuzere et al., 2014).	• Tonnes of carbon removed or stored per unit area per unit time (Zheng et al., 2013), total amount of carbon (tonnes) stored in vegetation (Davies et al., 2011). • Comparison with calculations of carbon consumption of equivalent non-NBS actions (e.g. through Life Cycle Assessment). • Allometric forest models of carbon sequestration, developed using proxy data obtained from Lidar data (Giannico et al., 2016). • Growth rates derived from Forest Inventory Analysis (Zheng et al., 2013).
• Monetary values: value of carbon sequestration by trees (Baró et al., 2014).	• Measurements of gross and net carbon sequestration of urban trees based on calculation of the biomass of each measured tree (i-Tree Eco model), translated into avoided social costs of CO_2 emissions (USD t^{-1} carbon).

Table 5 Examples of indicators for assessing the impact of climate adaptation actions at the meso and microscale

Indicators	Metric
• Temperature reduction	• Decrease in mean or peak daytime local temperatures (°C) (Demuzere et al., 2014). • Measures of human comfort e.g. ENVIMET PET — Personal Equivalent Temperature, or PMV — Predicted Mean Vote. • Heatwave risks (number of combined tropical nights (>20°C) and hot days (>35°C)) following Fischer, Schär, 2010, cited by Baró et al. (2015).
• Energy and carbon savings from reduced building energy consumption	• kWh/y and t C/y saved.

Challenge 2: Water Management

Growing urban populations, pollution, and economic activities in urban areas place water resources under severe stress, increasing pressure on the quality and quantity of water resources. The sustainable management of water resources is thus a key challenge for climate change mitigation and adaptation within cities in Europe and beyond (Carter, 2011). Climate change is expected to exacerbate existing problems connected to urban water resources by changing rainfall patterns and temperature regimes: for most European regions changes in the frequency and temporal distribution of precipitation are expected, with more intense rainfall events and longer periods of low precipitation levels, while overall precipitation quantities may decrease in some European regions (IPCC, 2014). Intense precipitation events will more frequently produce run-off quantities which exceed the capacities of urban sewerage systems, and cities along rivers and coastlines are at increased risk of flooding, whereas in some regions changes in rainfall patterns will further increase the risk of water scarcity in urban areas. Urban run-off water represents a threat for water quality because of the pollutant load it conveys. Areas along coastlines are further affected by salt water intrusion into groundwater, which is mainly driven by the overexploitation of aquifers. This trend could be accentuated in the future because of changing precipitation patterns (reduced rainfall quantities and prolonged drought) and rising sea levels (Wong et al., 2014).

NBS can help to tackle all three of these problems: flood risk, water scarcity and water quality, for example through using or mimicking the natural processes of infiltration, evapotranspiration and phytoremediation (Haase, 2015).

Potential actions and expected impacts

NBS can contribute to sustainable urban water management by increasing infiltration, enhancing evapotranspiration, providing storage areas for rainwater and removing pollutants. In order to prevent cities from being flooded, rainwater must be effectively discharged from areas where its accumulation can result in harm to humans and damage to infrastructure. Creating artificial water bodies or ecosystems within urban areas, or conserving and enhancing natural ones, can retain and store rainwater and urban run-off. The aim is to prevent precipitation water from directly flowing into the sewerage system (overcharging the system), thus reducing and delaying flood peaks and allowing controlled discharge. NBS for water retention include creation of natural spaces for temporary water storage (green areas and urban wetlands); improving infiltration (green areas, plants improving infiltration); and enhancing evapotranspiration (trees, green areas, parks). Storing stormwater and grey water can also conserve water for re-use both on-site (e.g. for maintenance of green areas) and for distant water needs (Young et al., 2014), thus providing additional water resources and reducing pressure on existing freshwater sources.

Using NBS rather than grey infrastructure for water storage allows for additional infiltration, contributing to the replenishment of ground water resources with potential positive impacts on water availability.

NBS for water storage and stormwater management can be combined with NBS for increasing water quality and water use efficiency by remediating some of the wastewater and urban run-off stored using phytoremediation, so that it can be reused, released into water bodies or allowed to infiltrate into the ground. Measures of this kind can contribute to reducing the depletion of freshwater resources and thus increase drought resilience (Table 6).

NBS may have the potential to transform an urban area with an impermeable surface into an urban water body with renewed ecosystems, with water flows and functions which can be integrated into the wider catchment. Nature-based or combined grey-green solutions for water management can also provide additional co-benefits with regards to:

1) Urban biodiversity
2) Improving the urban environment and living conditions, with benefits for human well-being and quality of life
3) Improvement of air quality, with benefits for human health
4) Improving the urban microclimate and reducing the urban heat island effect through the cooling effect of evapotranspiration;
5) Climate mitigation. As for all NBS, urban trees and green areas enhance direct carbon sequestration in plants and soils, but the quantities involved may not be significant enough for NBS to be considered an effective means for achieving local GHG reduction targets, especially when irrigation is required for maintaining plants (Baró et al., 2015; Pataki et al., 2011). However, green solutions may produce lower emissions compared to grey solutions (e.g. engineered solutions made from cement and other construction materials) that aim at the same goals.
6) Indirect economic benefits (increasing real estate values and tax income for local governments)

Indicators useful for assessing and monitoring NBS for water management comprise those relevant to the impacts of run-off, flood risk, water quantity and water quality (Table 7).

Table 6 Potential water management actions and expected impacts

Type of actions*	Reduce Run-off	Flood peak reductions/Increase in time to peak	Reduce load from run-off into sewerage systems	Reduce risk of flooding from flash-floods.	Reduce costs related to loads into sewerage systems	Reduce risk of flooding from rivers.	Increase infiltration/water storage	Enhance water retention capacity in the area	Reduce risk of damages from drought	Increase evapotranspiration	Reduce risk from urban heat island effect	Improve human health	Increase human well being	Improve water quality/reduce pollutants	Increase biodiversity	Increase carbon storage capacity
	P	P	P	I	I	I	P	S	I	P	I	S	S	S	S	S
• Renaturing urban waterbodies (opening channels, de-culverting, increase vegetation, greening waterfronts).		•				•	•			•	•	•	•	•	•	•
• Use of vegetation in urban areas (e.g. street trees, grassland, green roofs and facades, infiltration gardens and urban forests).			•	•	•		•	•	•	•	•	•	•	•	•	•
• Creation of artificial waterbodies for short term temporal water storage.	•	•	•	•	•			•	•				•			
• Creation of new vegetated surface waterbodies (ponds, drains, lakes, bio-retention cells).	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•
• Creation of new subsurface waterbodies for water storage.	•	•	•	•	•		•	•	•							
• Create areas for temporary flooding along rivers (floodplains) by moving flood protection infrastructures.	•					•				•			•	•	•	•
• Restore/create/increase wetlands in river-basins.	•					•	•	•	•	•				•	•	•

* *The letters represent the categories of indictors as defined in the DPSIR Framework (see* Gabrielsen and Bosch, 2003*)*
P – Pressure indicators, I – Impact indicators, S – State indicators

Examples of indicators

Table 7 Examples of water management indicators and their applicability at different geographic scales

Indicators	Measurement scale				
	mesoscale			microscale	
	Regional*	Metropolitan	Urban	Street	Building
Physical indicators					
• Run-off coefficient in relation to precipitation quantities (mm/%) (Armson et al., 2013; Getter et al., 2007; Iacob et al., 2014; Scharf et al., 2012).	●	●	●	●	●
• Flood peak reduction (Iacob et al., 2014), Increase in time to peak (Iacob et al., 2014) (%).	●	●	●	●	
• Reduction of drought risk (probability).	●	●			
• Increasing ground water availability, (depth to groundwater) (Feyen and Gorelick, 2004).	●	●			
• Absorption capacity of green surfaces, bioretention structures and single trees (Armson et al., 2013; Davis et al., 2009).				●	●
• Nutrient abatement, abatement of pollutants (%, nutrient load, heavy metals).	●				
• Ground water quality (nutrient load, heavy metals).	●				
• Increased evapotranspiration measured/modelled (Litvak and Pataki, 2016).	●	●	●	●	●
• Temperature reduction in urban areas (°C, % of energy reduction for cooling) (Demuzere et al., 2014).	●	●	●	●	
Economic indicators					
• Economic benefit of reduction of stormwater to be treated in public sewerage system (€) (Deng et al., 2013; Soares et al., 2011; Xiao and McPherson, 2002).	●	●	●		
• Reduction of inundation risk for critical urban infrastructures (probability) (Pregnolato et al., 2016).			●	●	
• Stage-damage curves relating depth and velocity of water to material damages (€) (de Moel et al., 2015).		●	●		

**Regional refers, in this context, to administrative/geographic levels which go beyond the urban /metropolitan level, including river basin management units*

Examples of methods for assessing the indicators

Methods for assessing the impacts of NBS relating to the management of urban water are based mainly on the modelling of water dynamics impacting the urban environment (water quantity and quality, flow and flow velocity, including evapotranspiration and infiltration, etc.), and on related economic impacts such as the cost of flood damage avoided by the measures implemented, as well as by the costs of the measures themselves. The important co-benefits provided by NBS implemented under Water Sensitive Urban Design

(WUDS), Low Impact Design (LID) or Sustainable Drainage (SUDS) schemes are assessed using qualitative methods which allow for scoring and comparison of different design options. Some specific methods follow.

Monetary assessments

- Estimation of avoided damages and costs from flooding (e.g. stage-damage curves relating depth and velocity of water to material damages ($) (de Moel et al., 2015).
- Avoided costs from increased water quantities to be treated in sewerage systems ($) (Deng et al., 2013; Soares et al., 2011; Xiao and Mc Pherson, 2002).
- Linear cost benefit assessments (CBA), introducing flexibility for adaptive solutions into the assessment of infrastructure measures (Deng et al., 2013).
- Extended cost benefit assessments (social cost benefit analysis, SCBA) including also social costs and benefits (taxes, subsidies, etc.) (City of Copenhagen, 2014; Leonardsen, 2013).

Non-monetary assessments

- Reduction of inundation risk for critical urban infrastructures (probability) based on hydraulic modelling and GIS assessment (Pregnolato et al., 2016).

Environmental assessments

- Assessment of run-off coefficients in relation to precipitation quantities (mm/%) (Armson et al., 2013; Getter et al., 2007; Iacob et al., 2014; Scharf et al., 2012).
- Modelling of flood peak reduction (Iacob et al., 2014).
- Experiments and measurements assessing the absorption capacity of structures (e.g. green roofs, bioretention structures) and single trees (Armson et al., 2013; Davis et al., 2009).
- Measurement of water and ground water quantity and quality (pollutants, nutrients) e.g. increasing ground water availability, (depth to groundwater) (Feyen and Gorelick, 2004).
- Modelling of options for stormwater management in the urban environment, including the quantification of SUDS benefits with the BeST model (Morales-Torres et al., 2016).

Integrated approaches (including co-benefits)

- Modelling of services provided by vegetation (trees) with the i-Tree Eco model — a suite of models and parameters based on experiences in different climatic zones for the assessment of ecosystem services produced by urban trees including stormwater management as well as carbon sequestration and other co-benefits (Soares et al., 2011).
- Assessment of wider social costs and benefits of water management strategies using the ecosystem services assessment framework. Cultural services, recreation, aesthetic values, and tourism values are mostly assessed using interviews and participatory approaches, including participatory mapping (Brown and Fagerholm, 2014; Haase, 2015; Iacob et al., 2014; Kati and Jari, 2016; Keeley et al., 2013; Raymond et al., 2009).
- CBA approaches: further to conventional and social integrated approaches (see case example of cloudburst plan in Copenhagen), introduce flexibility for adaptive solutions into the assessment of infrastructure measures (Deng et al., 2013).

Potential success factors and limiting factors (including synergies and trade-offs)

1) Reduction of run-off requires spaces for storing the water in urban areas. Unless combined uses of surfaces are possible (e.g. green roofs transforming existing or new flat or almost flat building coverings into water storage surfaces and sources for evapotranspiration; temporary storage in urban spaces such as squares or streets), these requests for urban space compete with other needs, and potentially are in conflict with the goal of increasing urban compactness, which in turn provides benefits by reducing the need for the transformation of rural areas into urban land with associated greenhouse gas emissions (Kati and Jari, 2016).
2) Maintenance of urban green areas in hotter climates requires irrigation, contributing to increases in urban water demand (Pataki et al., 2011); this represents a potential opportunity for water re-use schemes.
3) The use of infiltration for ground water recharge needs to be assessed with respect to the risk of conveying pollutants from runoff water into ground water. Aspects to be considered are the level and type of pollution in runoff water; soil characteristics with regard to filtration capacity; and characterization of rainfall events.
4) Absorption and retention capacities measured in terms of % of rainfall generally refer to low to medium range intensities of precipitation, and tend to decline with increasing intensity (Armson et al., 2013; Xiao and McPherson, 2002).
5) There is a potential trade-off between flood protection and water supply: although woodland can provide benefits for both flood protection and water supply through improving soil infiltration, certain fast-growing tree species such as pine and eucalyptus can reduce water supply due to evapotranspiration, which can be a benefit in regions prone to flooding but can also be a problem in arid or semi-arid regions (Harrison et al., 2014; Pérez-Soba etal., 2015).
6) Territorial scale: management and assessments normally relate to the catchment scale which often is not congruent with urban administrative boundaries, although measures to be assessed are often more local (Iacob et al., 2014), resulting in incongruent management (Dhakal and Chevalier, 2016; Keeley et al., 2013) and assessment scales (Demuzere et al., 2014a; Iacob et al., 2014).
7) Measurement scale: comparing between various natural flood management strategies is very challenging as quantitative measures use different parameters connected to flood risk, water storage and evapotranspiration; there is a need for a common structure of indicators (Iacob et al., 2014).
8) Drought resistant plant species often have particularly aggressive root systems which can produce significant damage to pavements, road surfaces, and adjacent buildings (Brindal and Stringer, 2013); other potential disservices are related to waterborne diseases, insects and existing pollution (Demuzere et al., 2014; Kati and Jari, 2016).

Case example: Copenhagen cloudburst plan pays off

The city of Copenhagen needed to tackle the issue of cloudbursts in the urban area. In a cost-benefit analysis, costs for implementation and management of two alternative approaches have been analysed, comparing the cost and benefits of hard (grey) infrastructure with a mixed approach combining NBS with hard infrastructure (Copenhagen, 2014; Leonardsen, 2013). The economic assessment was designed as an integrated valuation which extended beyond the consideration of the dimensions directly involved in their management, but also included wider socio-economic benefits and costs, such the benefits of avoided flood impacts, and the costs to society of increased fees for sewerage services. The improvement of environmental quality is a clear advantage of the solution of involving NBS. Consequently, the assessment also includes the environmental benefits provided by the additional green areas created, including the reduction of air pollution, and indirect benefits in the form of increased real estate prices.

Challenge 3: Coastal Resilience

Coastal areas occupy only a small proportion of the Earth's total land area, but contain more than one third of its population (Barbier, 2013) and supply a multitude of ecosystem services that provide widely acknowledged ecological, economic and social benefits. The equilibrium of coastal ecosystems is threatened, especially by urban development (Bell, 1997), and NBS are being increasingly used in maintaining or restoring some of the key ecosystem services provided by coastal areas. NBS can increase coastal resilience by protecting communities against extreme events such as storms and stabilizing shorelines against water erosion (Gedan et al., 2011). Furthermore, the use of multifunctional NBS in coastal areas can provide a range of other economic and cultural values (Narayan et al., 2016).

Potential actions and expected impacts

Table 8 Potential coastal resilience actions and expected impacts

Potential actions	Expected impacts
• Use NBS against coastal storms and sea level rises (Yepsen et a., 2016) and protect the population from these risks in combination with engineered structures (Stark et al., 2016).	• Increased population and infrastructures protected by a cost-effective creation of NBS (Cohen-Shacham et al., 2016) and increased resilience of cities.
• Promote various NBS in coastal areas that can maintain or restore valuable coastal ecosystems and coastal biodiversity (Barbier, 2013).	• Better protection and restoration of coastal ecosystems including valuable species and habitats (Gedan et al., 2011).
• Integrate development and conservation objectives using a better quantification of ecosystem services (Piwowarczyk et al., 2013).	• Sustainable development of coastal regions and reduced conflicts over resources or land-use (Narayan et al., 2016).

Examples of indicators

Table 9 Examples of indicators to assess elements of the coastal resilience challenge

Indicators	Measurement scale				
	mesoscale			microscale	
	Regional	Metropolitan	Urban	Street	Building
Physical indicators (Fagherazzi, 2014; Gedan et al., 2011; Grabowski et al., 2012; Stark et al., 2016).					
• Shoreline characteristics and erosion protection	●	●			
• Soil, temperature, drainage			●		
• Flooding characteristics	●	●			
Economic indicators (Gedan et al., 2011; Narayan et al., 2016; Shuster and Doerr, 2015).					
• Avoided damage costs			●	●	●
• Changes in property value				●	●
Social and education indicators (Piwowarczyk et al., 2013; Schuster & Doerr, 2015).					
• Recreation and public access		●	●		
• Number of students benefiting from education and research about coastal resilience/amenity	●				
Biological indicators (Bell, 1997; Yepsen et al., 2016).					
• Estimates of species, individuals and habitats distribution	●	●			
• Invasive and planted species	●	●	●		
• Algal bloom	●				
Chemical indicators (Grabowksi et al., 2012; Yepsen et al., 2016).					
• Concentration of nutrients			●	●	
• Salinity, pH			●	●	

Examples of methods for assessing the indicators

- Physical indicators: land-use and land cover changes, monitoring of physical parameters, number and extent of flooded areas, spatial analysis, GIS-based spatial analysis and modelling (Cohen-Shacham et al., 2016; Langemeyer et al., 2016; Liu et al., 2014).
- Economic indicators: cost-benefit analysis, price analysis, willingness to pay (Narayan et al., 2016).
- Social and educational indicators: surveys, estimates of the potential of NBS tourism, number of visitors, number and extent of research and education programs (Petrosillo et al., 2006; Voyer et al., 2013).
- Biological indicators: estimated habitat suitability index and modelling, species census, spatial distribution of vegetation, normalized vegetation index, monitoring using citizen applications (Baggett et al., 2014; Barbier et al., 2013; Neckles & Dionne, 2000).
- Chemical indicators: lab and field analysis of water quality, permanent monitoring systems (Ghervase et al., 2012; Orhel & Register, 2006).

Potential success factors and limiting factors (including synergies and trade-offs)

- Insufficient knowledge of the connection between NBS structure and function and the efficiency of coastal resilience habitats under different hydrodynamic and ecological conditions (Narayan et al., 2016).
- Both trade-offs and synergies in ecosystems services can occur: perceived problems can be caused by nature conservation, competing human uses or environmental pollution (Piwowarczyk et al., 2013).
- Lack of quantification or market values for the significant benefits provided by NBS for coastal resilience (Barbier, 2013).
- Further research and economic cost-benefit analysis is needed on the critical benefits that NBS provide for coastal resilience (Narayan et al., 2016).
- There are few studies which integrate both NBS knowledge and engineering principles at various spatial scales.

Case example: A stronger, more resilient coastal New York

The City of New York released a strategy in 2013 containing a comprehensive plan aimed at coastal protection, based on four main directions: improve coastal design and governance, provide storm protection, increase coastal edge elevation, and minimize upland wave zones (The City of New York, 2014). To address these challenges the municipality has used a variety of best practice options for enhancing coastal resiliency. Among the various NBS being used is the development of sand and dune surfaces which will improve the management of shoreline infrastructure (Seavitt Nordenson et al., 2015). The program was monitored using cost-benefit analysis to determine the efficiency of various methods in reducing risks, and also to plan additional developments in future coastal modelling and mapping, climate-related health vulnerabilities, and indicators and monitoring (The City of New York, 2014). The most noted outcomes of using NBS to improve the coastal resilience of New York City include reduced economic costs for the municipality and social benefits for the population.

Challenge 4: Green Space Management (including enhancing/conserving urban biodiversity)

Green and blue spaces (which are sometimes referred to as just “green spaces” for brevity) are areas based on natural and semi-natural elements which provide a range of ecological (Elmqvist et al., 2015), economic (Claus and Rousseau, 2012) and societal benefits (Gómez-Baggethun and Barton, 2013). A large variety of green and blue spaces exists, but all of them provide, to a greater or lesser extent, ecosystem services required for the resilience and sustainability of urban areas (Badiu et al., 2016).

Cities can strategically implement a combination of different existing, restored and new NBS using green space management plans (Andersson et al., 2014; van Veelen et al., 2015), starting from the principles present in European and national strategies and frameworks and local governance plans (Buijs et al., 2016; Elands et al., 2015), and adapting these to account for local conditions and practices, including the manner in which local people access the benefits of green and blue spaces.

Green and blue spaces are useful instruments for urban planners in achieving a sustainable urban structure, and they have a significant cultural and social dimension. They can provide elements characterizing the heritage and aesthetics of the area (Madureira et al., 2011; Niemelä, 2014), as well as being valued for recreation (Fors et al., 2015), social interaction (Kaźmierczak, 2013), education (Krasny et al., 2013) and supporting healthy living (Carrus et al., 2015).

Green and blue spaces are important for urban biodiversity in providing the required resources (Bennett et al., 2015) and habitats for species of interest (Niemelä, 2014), improving functional and structural connectivity at the urban level (Iojă et al., 2014) and increasing biodiversity knowledge or public support for conservation (Andersson et al., 2014).

Potential actions and expected impacts

Table 10 Potential green space management actions and expected impacts

Potential actions	Expected Impacts
• Inventories, hierarchizing and representation of green and blue spaces (e.g. Mapping and Spatial Planning) (Buijs et al., 2016; Davies et al., 2015; Hansen et al., 2015; Martos et al., 2016).	• Clear accounts of existing, restored, modified and new NBS (Buijs et al., 2016; Buizer et al., 2015; Elands et al., 2015).
• Set clear and measurable quality and quantity requirements for existing and new NBS (Mazza et al., 2011; Pinho et al., 2016).	• Increase of quality and quantity of green and blue existing, restored and new NBS (Gómez-Baggethun and Barton, 2013).
• Make use of innovative, interdisciplinary planning methods for green space co-design and co-implementation, including development of innovative social models for long-term positive management (e.g. Citizen Engagement for Health) (Derkzen et al., 2015; Fernandez et al., 2015).	• Increased stakeholder awareness and knowledge about NBS and ecosystem services, as well as citizen participation in the management of NBS (Filibeck et al., 2016; Hansen et al., 2015; Mell et al., 2013).
• Create, enlarge, fit out, connect and improve green and blue infrastructure by implementing NBS projects (Kazmierczak and Carter, 2014; Landscape Institute, 2009; Madureira et al., 2011).	• Improve the connectivity and functionality of green and blue infrastructures (Brown et al., 2015; Niemelä, 2014).
• Conserve, improve and maintain existing NBS areas in respect to biodiversity (Elands et al., 2015; Elmqvist et al., 2015).	• Increase achievement of biodiversity targets (Elands et al., 2015; Elmqvist et al., 2015).

Examples of indicators

Table 11 Examples of green space management indicators and their applicability at different geographic scales

Indicators	Measurement scale				
	mesoscale			microscale	
	Region	Metropolitan	Urban	Street	Building
• Distribution of public green space – total surface or per capita (Badiu et al., 2016; Gómez-Baggethun and Barton, 2013; La Rosa et al., 2016).	•	•	•		
• Recreational (number of visitors, number of recreational activities) or cultural (number of cultural events, people involved, children in educational activities) value (Kabisch and Haase, 2014).	•	•	•	•	
• Accessibility (measured as distance or time) of urban green spaces for population (Tamosiunas et al., 2014).	•	•	•	•	
• Changes in the pattern of structural and functional connectivity (Iojă et al., 2014).	•	•	•		
• Species richness and composition in respect to indigenous vegetation and local/national biodiversity targets (Cohen et al., 2012; Krasny et al., 2013).	•	•	•	•	•

Examples of methods for assessing the indicators

- Categorizing and rating of different NBS types and their impact potential (Akbari et al., 2016; Bowler et al., 2010b; Cvejić et al., 2015; Derkzen et al., 2015; Lehmann et al., 2014; Manso and Castro-Gomes, 2015; Perez et al., 2011; Shishegar, 2015).
- Comparing the overall linkage between NBS sites and the status of NBS implementation (Botzat et al., 2016).
- Questionnaires applied to the population for the recreational and cultural benefits of green spaces (Kabisch and Haase, 2014).
- Mapping of user values attached to green/blue areas (Raymond et al., 2016b; Vierikko and Niemelä, 2016; Wang et al., 2015a).
- Digital mapping (e.g., remote sensing, GIS) of the potential for NBS and status of implementation (Badiu et al., 2016; Gómez-Baggethun and Barton, 2013; La Rosa et al., 2016).
- Ecological and connectivity modelling for biodiversity benefits (Pino and Marull, 2012; Pirnat and Hladnik, 2016).
- Identification of NBS indicators using field surveys, (random) located plots, which are regularly re-surveyed.

Potential success factors and limiting factors (including synergies and trade-offs)

- Success factors:
  - The long-term achievement of biological and cultural diversity;
  - The clear merging of old and new NBS, as highlighted by the concepts of transition and conservation (Andersson and Barthel, 2016; Pirnat and Hladnik, 2016).
- Limiting factors:
  - Challenges associated with lack of expertise in general and participatory management of green space maintenance (Andersson et al., 2014);
  - The complexity in planning and implementing NBS. For example, differing property ownership and competition demands, neglecting multi-functionality (Andersson et al., 2014);
  - Inadequate communication and focus on ecosystem disservices (Gómez-Baggethun and Barton, 2013; Tyrväinen and Miettinen, 2000);
  - Issues associated with the Technology Readiness Level of NBS in respect to climate change and ecological target value (Raimondo et al., 2015);
  - The complex synergies between NBS, governance and community engagement processes at an operational and financial level (Andersson et al., 2014; Kati and Jari, 2016).

Case example: Green space management in Vienna, Austria

The city of Vienna has had an ongoing large scale Green Infrastructure Strategy for more than two decades. It contributes to numerous national Strategies (e.g. Biodiversity Strategy Austria, Netzwerk Natur, Natura 2000), is embedded in urban plans (e.g. Urban Heat Island Strategy Plan, City Development Plan 2025) and covers existing, recovered and new NBS such as small to large scale parks, trees, rivers and streams, green bridges, green roofs, green walls and large scale Nature Protection Areas (e.g. Naturschutzgebiet Donauauen). These NBS are mapped in the city's Green Cadastre System and therefore undergo a continuous monitoring process (mapping of current stock and future potential) in regards to specific objectives and goals (e.g. to reach a certain percentage of greened flat roofs, or contribute to biodiversity conservation through protected bird and butterfly habitats). Various implementation plans tackle the city as a whole, as well as specific areas (districts) and individual buildings. The city supports NBS implementation through different funding mechanisms for private owners and businesses (e.g. funding of planning and implementation processes) linked to certain target areas (e.g. regulation of the percentage area of green surfaces at the building plot level, integrated in the building plans). To encourage stakeholder involvement and citizen ownership, the city has empowered their districts and Local Agenda 21 movements by providing dedicated knowledge support from key sources (e.g. the municipal department for environmental protection) in multi-stakeholder planning and participation events, and they receive tailored communication material and training from the government. Vienna is combining existing technologies into even more effective investments, e.g. they propose to combine rooftop solar panels with green roofs in order to increase energy production rates and biodiversity, but the city also aspires to reach the next level. At the moment, the city is investing in technology readiness and implementation plans for stormwater and rainwater management technologies such as bio-swales, raingardens and other greened active soils. Soon the city will implement a tax system for wastewater treatment, as applied in German cities: treating rainwater on-site with green technologies will save the costs of using the sewage service. An action task force is currently assessing the potential for integrating green walls into social housing investments in order to reduce social and gender disparities and inadequacies in public housing.

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Challenge 5: Air Quality

Air quality is a major concern worldwide, particularly in urban areas, due to its direct consequences on human health. In the political agenda, air quality issues can be coupled with climate change mitigation policies as described in Challenge 1, since many actions aimed at air quality improvement (such as reducing fossil fuel combustion) involve a concurrent reduction of GHG emissions. NBS based on the creation, enhancement, or restoration of ecosystems in human-dominated environments also exploit the synergy between ecosystem processes that regulate pollutants and CO_2 in the atmosphere. Vegetation affects air quality mainly through the removal of air pollutants (PM_{10}, NO_2, O_3, CO, SO_2) through dry deposition, although certain species can also emit biogenic volatile organic compounds (BVOC), which are ozone precursors. However, vegetation can also reduce the air temperature, which reduces the emission of BVOCs and slows down the creation of secondary pollutants such as ozone (Wang et al., 2015b; Calfapietra et al. 2013). Despite their limited contribution compared to the overall production of pollutants and GHG emissions at the city level, measures to tackle air quality by enhancing green infrastructure can be considered a good investment due to the number of co-benefits that they produce and their contribution to amenity value over time (Baró et al., 2015).

Potential actions and expected impacts

Table 12 Potential air quality actions and expected impacts

Potential actions	Expected impacts
• Planting trees: o in private domestic gardens (Davies et al., 2011); o along the streets (Baró et al., 2014; McDonald et al., 2007; Mullaney et al., 2015); o in urban parks (Yin et al., 2011).	• Reduction of air pollutants through increased deposition (Baró et al., 2014; Bealey et al., 2007; Grote et al. 2017; Tallis et al., 2011). • A number of co-benefits including stormwater run-off mitigation, microclimate regulation through shading, habitat and food provision for biodiversity, noise shielding, and recreational and cultural services (Mullaney et al., 2015).
• Building green roofs (Li and Babcock, 2014) and green walls (Joshi and Ghosh, 2014).	• Capture of air pollutants through deposition (Speak et al., 2012). • A number of co-benefits both for the outdoor (e.g. stormwater retention) and for the indoor environment (i.e., reduced energy needs and a more pleasant environment due to the higher thermal and noise insulation) (Wang et al., 2016).
• Maintaining existing green infrastructure (Davies et al., 2011).	• A wide range of co-benefits including shading, water retention, dry precipitation, infiltration.

Examples of indicators

Table 13 Examples of air quality indicators and their applicability at different geographic scales

Indicators	Measurement scale				
	mesoscale			microscale	
	Regional	Metropolitan	Urban	Street	Building
• Non-spatial indicators of gross quantities: annual amount of pollutants captured by vegetation (Bottalico et al., 2016).	•	•	•	•	
• Non-spatial indicators of net quantities: net air quality improvement (pollutants produced – pollutants captured + GHG emissions from maintenance activities) (Baró et al., 2014).		•	•	•	
• Non-spatial indicators of shares: share of emissions (air pollutants) captured/sequestered by vegetation (Baró et al., 2014).		•	•	•	
• Spatial indicators: pollutant fluxes per m2 per year (Manes et al., 2016; Tallis et al., 2011).		•	•	•	
• Monetary values: value of air pollution reduction (Manes et al., 2016); total monetary value of urban forests including air quality, run-off mitigation, energy savings, and increase in property values (Soares et al., 2011).		•	•		
• Other indicators: health impact indicators such as premature deaths and hospital admissions averted per year (Tiwary et al., 2009).	•	•	•		

Examples of methods for assessing the indicators

- The i-Tree Eco (updated version of the former UFORE model) suite is available to quantify air pollution reduction and global climate regulation in biophysical and monetary terms using field data collected through a defined sampling protocol (Nowak et al., 2008).
- The "Tiwary method" can be applied to calculate pollution reduction by vegetation, as an alternative to the UFORE model (Tiwary et al., 2009).
- Spatially-explicit models consider the differences in both urban forest structure and pollution concentrations in the different areas (Escobedo and Nowak, 2009). Manes et al. (2016) proposed a method based on the pollution flux approach to map air purification using spatially-explicit data on ecosystem types and characteristics (particularly leaf area index, LAI), and pollution distribution. i-Tree Eco can also be run in a spatially-explicit domain, in order to obtain spatial measures of air purification (Bottalico et al., 2016).
- Models to calculate deposition and capture of pollutants usually adopt hourly meteorological and pollution concentration data. Tallis et al. (2011) proposed and tested a useful approach that uses seasonal data instead.
- Other (complex) numerical methods describe the interactions between vegetation and pollutants at the micro scale (Joshi and Ghosh, 2014) or simulate the emission and deposition processes based on trajectory and dispersion models, e.g. the atmospheric transport FRAME (Fine Resolution Atmospheric Multi-species Exchange) model (Bealey et al., 2007).
- The economic value of air purification can be measured using avoided costs for health care or replacement costs for artificial treatment. Co-benefits can also be estimated: indoor energy savings can

be quantified in terms of avoided energy expenditures; the value of aesthetic quality is commonly estimated through "hedonic pricing" (increased property values) or "willingness to pay" methods (Wang et al., 2015a); and the value for carbon sequestration can be based on international carbon market prices (Zheng et al., 2013).

Potential success factors and limiting factors (including synergies and trade-offs)

- The effect of the urban forest on air quality accounts only for a small percentage (around 2%) of the overall concentration of PM_{10} in cities (Baró et al., 2014; Baumgardner et al., 2012; Bottalico et al., 2016), and makes a modest contribution relative to city annual emissions of both GHG and NO_2 (less than 1%) (Baró et al., 2014). As a consequence, the effectiveness of NBS is limited by the availability of space: planting 25% of the available space in Glasgow and the East Midlands would reduce PM_{10} concentrations by 0.4% and 3% respectively, while planting all the available land in the city of Glasgow would not produce more than a 1.2% reduction (McDonald et al., 2007). Therefore, NBS must be coupled with mitigation policies aimed at reducing emissions inside and outside urban areas.
- The effectiveness of reducing air pollution through urban forests presents mixed results depending on the type of intervention and the context of application (Escobedo and Nowak, 2009).
- Urban trees may also produce allergens and can contribute to air pollution through the emission of biogenic volatile organic compounds (BVOC), which can lead to the formation of secondary ozone, carbon monoxide and Biological Particulate Matter; thus a quantification of the "net" air quality improvement should take into consideration this ecosystem disservice (Baró et al., 2014; Calfapietra et al. 2013, Grote et al., 2017). Carbon monoxide formation may offset the amount captured through deposition in peri-urban ecosystems (Baumgardner et al., 2012).
- Depending on wind intensity and direction, tree shapes and arrangements, and the 3-D configuration of the street canyon, street trees have different local effects on the dispersion of air pollutants and may induce a local increase in concentration (Amorim et al., 2013), particularly of NO_2 and environmental carbon (Vos et al., 2013).
- Current designs for green walls tend to have high irrigation demands and relatively short life-spans (Manso and Castro-Gomes, 2015).
- Street trees in urban areas may damage pavements and infrastructures, and induce allergies to pollen. In addition, trees suffer from vandalism, higher temperatures, and water and nutrient scarcity if not properly planted and managed (Escobedo et al., 2011; Mullaney et al., 2015).
- Although not as effective as street trees, due to the greater distance from the major source of pollutants and the lower surface area exposed, green roofs can be a good option for reducing air pollution because they are easier to install and to manage than trees, but the right species must be chosen to maximize the effect (Speak et al., 2012) and the potential release of polluted run-off rich in phosphorus and nitrogen must be controlled through careful design (Li and Babcock, 2014).

Case example: Managing air quality in Barcelona

Barcelona is one of the biggest metropolitan cities in Europe and one of the densest and most compact urban areas, with a population density of around 16,000 inhabitants per square kilometre. Despite its density, green spaces represent 36.8% of the city area and a survey in 2008 counted more than 153,000 street trees across the city, which represents double the number from 30 years earlier. Starting from 2009, a strong commitment to urban environmental issues guided the city to develop a series of strategies and measures that address through an integrated approach a wide range of sectors, from the development of sustainable mobility, to the reduction of GHG emissions through increased energy efficiency, to the reduction and recycling of wastes. The lines of action defined in 2009 include a significant increase in numbers of street trees; the provision of green spaces close to citizens, with initiatives like “Green 5 Minutes from Home” and “Pocket Gardens”; the conversion of courtyards into green spaces; the creation of allotment gardens; and a new Green Strategy for the city (Ajuntament de Barcelona, 2009). The process was supported by a scientific study that began in January 2009 with the aim of quantifying the ecosystem services provided by Barcelona’s urban forest. The assessment was based on a wide survey on the state of the green infrastructure of the city, and the UFORE model was apply to quantify service provision and economic values (Baró et al., 2014; Chaparo and Terradas (2009). In 2013, a new “Green infrastructure and biodiversity plan to 2020” was approved (Ajuntament de Barcelona, 2013). Its diagnosis of the state of green infrastructure in the city clearly links the different types of urban ecosystems and their biodiversity to the provision of a series of ecosystem services, including air quality and climate change mitigation and adaptation. The proposed measures include an increase in street tree number and species diversity, the provision of more soil for street trees, and a further increase in the number and quality of green spaces in the city.

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Challenge 6: Urban Regeneration

Urban regeneration aims at improvements in the economic, physical, social and environmental conditions of an area that has been subject to negative change and is considered vulnerable (non-resilient) (Tallon, 2013). It can include aspects of (local) business development, housing growth and improvement, community building and environmental improvement (Tyler et al., 2013). Attention also needs to be paid to ecological restoration across scales (Andersson et al., 2014) and aspects of social justice. Urban regeneration brings new opportunities for cities to reconsider their planning strategies in the context of limited available space, deprived areas, social inequities or global environmental changes (Couch et al., 2008). NBS projects need to consider the interlinkages between urban regeneration, aesthetic appeal, urban development/building culture, urban structure, design and aesthetics, urban ecology and its relation to energy and water use (Hemphill et al., 2004; Laprise et al., 2015; Sepe, 2013). For example, landscapes that look well-cared for discourage crime, and social capital may be nurtured by physical evidence of care (Nassauer and Raskin, 2014).

Potential actions and expected impacts

Table 14 Potential urban regeneration actions and expected impacts.

Potential actions	Expected impacts
• Enforce micro-scale and cross-scale interactions, consider urban hinterland and "distant landscapes" *sensu* Andersson et al. (2014). • Increase ecological connectivity across NBS sites. • Enhance biodiversity and community engagement (e.g. creating community gardens or pocket parks). • Design rain gardens or facade greening systems.	• Greater ecological connectivity across urban regeneration sites, and across scales. • Increased extent of greenery on urban facades.
• Support energy efficiency in building design and layout, building form, infiltration and ventilation, insulation, heating and lighting (Hemphill et al., 2004). • Encourage re-use of building materials in new construction and promote efficient use of resources, materials, and construction techniques that maximise the effective life-cycle of the building (Hemphill et al., 2004).	• More energy efficient building design and long-term use. • Reduction in the amount of building material going to land-fill. • Reduced use of energy in the production of building materials and the construction of new buildings.
• Convert brownfield to green areas in urban regeneration projects (Mathey et al., 2015). • Design for: o richness in urban environments, such as the promotion of street life, natural surveillance, visual richness, public art, and street furniture (Biddulph, 2011); o diversity in use, such as mix of people, mix of uses, appropriate densities and visual diversity (Biddulph, 2011); o ease of movement, including through movement, priority given to public transport, priority given to innovative parking, meeting needs of people with sensory impairments (Biddulph, 2011).	• Local citizens have a say in the design and management of homes and office buildings, contributing to social justice outcomes. • Increased amount of green open space for residents. • Increased cultural richness and diversity in urban areas, as well as improved ease of movement.
• Provide the urban brand with a narrative and a value aimed at changing the perception of potential users or visitors, whether they are citizens, international tourists or investors.	• Changing images of the urban environment, attracting new residents, visitors, tourists and investors.

Examples of indicators

Table 15 Examples of urban regeneration indicators and their applicability at different geographic scales

Indicators	Measurement scale				
	mesoscale			microscale	
	Regional	Metropolitan	Urban	Street	Building
Urban green indicators					
• Urban green: Index of biodiversity, provision and demand of ecosystem services.	•	•	•	•	•
• Ecological connectivity (Pino and Marull, 2012).	•	•	•		
• Accessibility (Schipperijn et al., 2010): distribution, configuration, and diversity of green space and land use changes (multi-scale; Goddard et al., 2010).	•	•	•		
• Ratio of open spaces to built-form.				•	•
• Reclamation of contaminated land: percentage of contaminated area reclaimed.			•	•	•
Building efficiency and environmental design indicators					
• Reclamation of building materials: percentage reclaimed from existing buildings.					•
• Energy efficiency: building materials/ construction methods based on points awarded according to energy efficiency checklist.					•
• Incorporation of environmental design: percentage of total building stock.					•
• Land devoted to roads: percentage of site area occupied by roads.	•	•	•	•	
Socio-cultural indicators					
• Conservation of built heritage resources: percentage of built form retained for culture.					•
• Land dedicated to pedestrians: percentage of road network.	•	•	•	•	
• Public transport links: walking distance to nearest facilities.			•	•	
• Access to open space: average journey time for residents/employees by foot or average distance to sports centre, recreation area, or green space.		•	•	•	
• Access to cultural facilities: average journey time for residents on foot or average distance to cultural centre.		•	•	•	
• Access to housing: affordability and choice.	•	•	•		
• Level of devices contributing to the safety of users in the neighbourhood: lighting of common areas, access control, presence of technical, or specialized staff, etc.					•

Examples of methods for assessing the indicators

- Document and analyse the best replicable practice of NBS in multidisciplinary terms.
- Biodiversity mapping (in a temporal context; Ramalho and Hobbs, 2012), LIDAR, spatial analysis and ES mapping (considering ES bundles and functions, synergies and trade-offs, (de Groot et al., 2010; Fisher et al., 2009; Haase et al., 2012; Pauleit and Duhme, 2000), integrated design (Farr, 2011; McHarg, 1969).

- Measurement on maps and city plans (Laprise et al., 2015).
- Qualitative analysis of interventions on buildings and surroundings (Laprise et al., 2015).
- Quantitative analysis of building typologies, measures and devices supporting flexibility (Laprise et al., 2015).
- Energy balance checklists. Values depend on whether it is a new construction or a renovation, according to the building type (Laprise et al., 2015).
- Structured interviews with architect/developer (Hemphill et al., 2004).
- Interviews and surveys with local communities (see participatory planning and governance).

Potential success factors and limiting factors (including synergies and trade-offs)

- There is a potential trade-off between NBS implementation/introductions in urban environments and environmental justice, particularly concerning issues of gentrification (Checker, 2011; Dooling, 2009; Wolch et al., 2014). Such a trade-off requires effective identification.
- The success of urban regeneration projects partly depends on integrating biodiversity, urban greenery and ecosystem services with the built form; supporting projects at multiple scales (Basnou et al., 2015); supporting grant schemes; innovative designs (Dramstad et al., 1996); supporting bridging organizations (Chapin et al., 2010); and considering people´s different views on urban climate adaptation (Derkzen et al., 2017).
- Limiting factors include a lack of data on pollutants, epidemiology, and cartography; poor institutional support and economic incentives; a lack of involvement of local communities; conflicts of interests; failure to build-up multidisciplinary teams and to assess priority areas; and poor communication plans to address inclusiveness (Daily et al., 2009; Kabisch, 2015; Sheppard, 2005).
- Future research and practice needs to address institutional changes and behaviours, find a shared language to communicate NBS, encourage networking (Connolly et al., 2014; Deakin and Allwinkle, 2007), develop a place-based approach and holistic strategies for urban regeneration (http://www.turas-cities.eu/city_strategies; Wansborough and Mageean, 2000), enhance inclusive learning, and support grant schemes and special green funds (e.g. special funds for schools for tree planting, or for farmers).
- Often there is a conflict between the commercial drivers of urban regeneration, and environmental and social goals. Sustainable urban regeneration thus requires changes to institutional behaviour, and new ways for communicating the effectiveness of NBS (Connolly et al., 2014; Deakin and Allwinkle, 2007).

Case examples: Urban gardens in Barcelona; the Green Living Room, Stuttgart; The Edge building in Amsterdam.

In Barcelona, active ageing and social inclusivity programs are encouraged in urban allotments and community gardens. Elderly low-middle income and migrant people are among the main beneficiaries of such initiatives (Camps-Calvet et al., 2016). Barcelona has also a large network of school gardens. The city recently developed the *Pla Buits* (Empty Spaces Plan), designating some of the city allotments for people at risk of social exclusion.

A *Green Living Room* of innovative design was created in Stuttgart in order to tackle the urban heat island. The room promoted higher biodiversity, cooling effects and increased the permeable surface and water retention. Urban Climate Comfort Zones and priority areas were used to determine NBS which better addressed climate change impacts.

The Edge in Amsterdam is the greenest building in the world and uses 70% less energy than the average office building (Randall, 2015). The green space that separates the building from the nearby motorway acts as an ecological corridor, allowing animals and insects to cross the site safely. Bird and bat boxes are included in the landscaping to support pollination of flowering plants.

Energy efficiency, environmental design and socio-cultural aspects embedded in this building include:

1) Thick load-bearing concrete helps regulate heat, and deeply recessed windows reduce the need for shades, despite direct exposure to the sun;
2) Mesh panels between each floor let stale office air spill into open space, where it rises and is exhaled through the roof, creating a loop of natural ventilation;
3) The slanted roof provides daylight and a sound buffer from the adjacent highway and train tracks;
4) Every workspace is within 7 meters (23 feet) of a window;
5) A quarter of this building is not allocated to desk space but is a place to meet, enabling ideas to be readily shared.

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Challenge 7: Participatory Planning and Governance

Nature-based solutions require planning approaches and governance architectures that support accessibility to green spaces, while maintaining their quality for the provision of ecosystem services. In urban planning, attention has been paid to methods and approaches to bridge different types of knowledge on urban systems (Colding and Barthel, 2013; Frantzeskaki and Kabisch, 2016) and to develop integrated plans for designing and implementing nature-based solutions (Krasny et al., 2014; Luyet et al., 2012). Studies have also focussed on different factors that contribute to the integration of ecosystem thinking in urban planning, considering the understanding of interests and perceptions of citizens (Buchel and Frantzeskaki, 2015), and examining the changes in policy narratives when incorporating the ecosystem services framework in planning (Hansen et al., 2016).

Potential actions and expected impacts

Table 16 Potential urban regeneration actions and expected impacts

Potential actions	Expected impacts
• Design knowledge co-production processes to bring openness, transparency in governance processes, and legitimacy of knowledge from citizens/civil society, practitioners and policy stakeholders (Crowe et al., 2016; Frantzeskaki and Kabisch, 2016; Specht et al., 2016). • Create different institutional spaces for cross-sectoral dialogue and interactions of different stakeholders for strengthening/fostering adaptive co-management and knowledge sharing about urban ecosystems (Crowe et al., 2016; Dennis and James, 2016; Fors et al., 2015; Frantzeskaki and Tilie, 2014; Ugolini et al., 2015). • Enable cross-sectoral partnerships for NBS design, implementation and maintenance (Crowe et al., 2016; Krasny et al., 2014; Specht et al., 2016; Ugolini et al., 2015).	• Legitimate different forms and systems of knowledge in participatory planning processes, empowering citizens/civil society, practitioners and policy stakeholder involvement in NBS projects. • Social learning about the location and importance of different types of socio-cultural values for NBS, enabling NBS to be designed in line with community aspirations and expectations. • Policy learning leading to more efficient design, delivery, and monitoring of NBS. • Inter-departmental collaboration leading to NBS designs for multi-functionality. • Improved co-ordination of NBS strategies within and across levels of governance.
• Support processes that enrich or regenerate ecological memory for restoring urban ecosystems with NBS (Colding and Barthel, 2013).	• Improved understanding of different perceptions of urban nature. Integration of these understandings into urban design is likely to lead to higher levels of ownership of NBS by local communities.
• Promote and work towards creative designs of NBS in cities that are adaptive over time (Collier et al., 2013; Vandergert et al., 2015).	• NBS that are flexible to changing environmental, social or economic conditions.
• Support community-based projects on greening and restoring urban green spaces that also ensure accessibility to these spaces and stewardship (Dennis and James, 2016; Krasny et al., 2014).	• Increased accessibility to green open space, supporting social justice outcomes.

Examples of indicators

Table 17 Examples of indicators to assess participatory planning and governance impacts, and their applicability at different scales

Indicators	Measurement scale				
	mesoscale			microscale	
	Regional	Metropolitan	Urban	Street	Building
• Openness of participatory processes (Frantzeskaki and Kabisch, 2016; Luyet et al., 2012; Uittenbroek et al., 2013).	•	•	•	•	
• Legitimacy of knowledge in participatory processes (Frantzeskaki and Kabisch, 2016; Luyet et al., 2012).	•	•	•		
• Social learning concerning urban ecosystems and their functions/services (Colding and Barthel, 2013).	•	•	•	•	
• Policy learning concerning adapting policies and strategic plans by integrating ecosystem services and possibly their valuation (Crowe et al., 2016; Uittenbroek et al., 2013; Vandergert et al., 2015).	•	•	•	•	•
• Perceptions of citizens on urban nature (Buchel and Frantzeskaki, 2015; Colding and Barthel, 2013; Gerstenberg and Hofmann, 2016; Scholte et al., 2015; Vierikko and Niemelä, 2016).	•	•	•		
• Social values for urban ecosystems and biodiversity (Brown and Fagerholm, 2014; Kenter et al., 2015; Polat and Akay, 2015; Raymond et al., 2014, 2009; Scholte et al., 2015).	•	•	•		

Examples of methods for assessing the indicators

- Action research, case study, surveys (Specht et al., 2016).
- Q method (Buchel and Frantzeskaki, 2015).
- Narrative analysis, statistical analyses (Buchel and Frantzeskaki, 2016; Gerstenberg and Hofmann, 2016; Hansen et al., 2016).
- Fuzzy cognitive mapping (Gray et al., 2015).
- Actor–network analyses, interpretative methods (Frantzeskaki and Tillie, 2014; Hansen et al., 2016).
- Environmental valuation methods (monetary and non-monetary) (Kenter, 2016; Raymond et al., 2014; Scholte et al., 2015).
- Ecological psychology methods (see Heft, 2012, for an overview).
- Environmental psychological methods (see Gifford, 2014, for an overview).
- Expert-based approaches (Scholte et al., 2015).
- Knowledge synthesis (Pullin et al., 2016).

Potential success factors and limiting factors (including synergies and trade-offs)

- From urban environmental governance literature, the processes of interaction, collaboration and co-creation of new institutions for urban ecosystem restoration and management have been identified as critical (Frantzeskaki and Tillie 2014). In these processes, multiple actors participate and different actors can be the agents facilitating and steering towards the desirable goal/aspiration (Crowe et al., 2016; Dennis and James, 2016). Recent years show mounting evidence of bottom-up organisation, through community-based initiatives and grass-root movements, of greening vacant spaces, reclaiming and restoring brownfields, and driving an urban transition towards more liveable and healthy environments in cities (Dennis and James, 2016).

- However, it needs to be recorded that current research on participatory planning and urban environmental governance largely reports cases from north-western Europe, North America, Australia and South Africa showing a gap of knowledge about suitable processes for planning and governance from other countries (Fors et al., 2015).

Case example: Engaging residents in blue open space management, Helsinki, Finland.

Helsinki has over 130 km of shoreline and over 315 islands. The shoreline and archipelago have a rich cultural history and there are also significant natural areas for recreation, especially on the eastern shores of Helsinki. Opening this shoreline for everyone has been a long-term goal of city planning in Helsinki (City of Helsinki, 2014). In 2014 approximately 30,000 residents, aged between 15 and 75 years old, were invited to participate in a public participation geographic information system (PPGIS) study aimed at understanding the perceived environmental qualities of blue open spaces in the Helsinki Metropolitan Area. Activity data were collecting using Maptionnaire, which is an online PPGIS tool for the collection of experiential knowledge about the urban environment and its uses and values (Kyttä & Kahila, 2011). Residents were asked: “*What water and waterside areas do you enjoy in the Helsinki region? Use the buttons below to mark it on the map! You may mark as many locations as you wish.”* This participatory planning method provided a means for spatially targeting recreation, sport and leisure infrastructure to different user groups (Raymond et al., 2016b). The data collection in this PPGIS study was also carefully designed to meet the information needs of Environmental and Sports departments, who are responsible for the management and maintenance of blue open spaces in Helsinki. An online planning support service was created to ensure the usability of produced knowledge for NBS in urban areas. The city planning department of the City of Helsinki has also found the data useful in marine spatial planning.

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Challenge 8: Social Justice and Social Cohesion

Social justice recognises that society comprises of a diverse set of social groups, with varying requirements, rights and duties that need mutual support, co-operation and acceptance (Zajda et al., 2007). In green infrastructure planning, most attention has been devoted to environmental justice, which includes elements of distribution, procedure and recognition (Rutt and Gulsrud, 2016). Distributional justice relates to the unequal distribution, both social and spatial, of environmental qualities (Perez et al., 2015); procedural justice relates to inclusiveness and fairness in processes and in rule enforcement (Schlosberg, 2007); and recognition-based justice focuses on the acknowledgement of the elderly and typically excluded social groups (e.g. migrants, women, persons with disabilities) (Fraser, 2009). Support for environmental justice can also support social cohesion in urban areas. For example, supporting processes which enable immigrants to feel comfortable in their living environment supports intercultural understanding (de Vries et al., 2013; Leikkilä et al., 2013). Social cohesion is also a multi-dimensional concept, taking into account of structural and cognitive aspects as described below.

Potential actions and expected impacts

Table 18 Potential social justice and social cohesion actions and expected impacts.

Potential actions	Expected impacts
• Distribute various types of NBS across urban areas to ensure a range of ecosystem services and experiential qualities of place are available to people from different socio-economic backgrounds (Raymond et al., 2016b).	• A greater diversity and number of people having the opportunity to experience and enjoy the natural environment through investments in NBS in multiple areas (Natural England, 2014).
• Support experiential learning and capacity building programs on NBS in ways that meet the varying requirements, rights and duties of local residents (Krasny et al., 2013).	• An increase in communities' sense of ownership of local natural places (Natural England, 2014). • More people having opportunities for learning about nature and gaining new skills; building trust, tolerance and respect between groups.
• Actively engage excluded social groups in the design, delivery and monitoring of NBS, as well as in the rules to support the governance of NBS.	• NBS designed, delivered and monitored in ways that reflect the needs and interests of typically excluded social groups.
• Build the capacity of typically excluded groups to participate in NBS decision-making processes. Capacity building can include efforts directed to improving basic literacy and numeracy, physical security, employment, information and recognition as a citizen (Rutt and Gulsrud, 2016).	• Typically excluded groups having the capacity to actively engage in NBS decision-making processes, thereby supporting social cohesion among diverse socio-economic groups.

Examples of indicators

Table 19 Examples of social justice and social cohesion indicators and their applicability at different geographic scales

Indicators	Measurement scale				
	mesoscale			microscale	
	Regional	Metropolitan	Urban	Street	Building
Social justice (informed by the capability framework of social justice (Comim et al., 2008; Nussbaum, 2011; Sen, 2005).					
• The availability and distribution of different types of parks and/or ecosystem services with respect to specific individual or household socioeconomic profiles and landscape design (Cohen et al., 2012; Ernstson, 2013; Ibes, 2015; Kabisch and Haase, 2014; Raymond et al., 2016b; Shanahan et al., 2014).		•	•	•	
• Access to financial resources, including indicators of income per capita in a given neighbourhood, or urban area (Klasen, 2008).			•	•	
• Bodily integrity: being able to move freely from place to place; to be secure against violent assault, including indicators of crime by time of day (Felson and Poulsen, 2003).				•	•
• Senses, imagination and thought: being able to use the senses, to imagine, think, and reason about the environment, informed by indicators of levels of literacy, mathematics and science knowledge (Chen and Luoh, 2010; Elliott et al., 2001).				•	•
• Emotions: being able to have attachments to things and people outside ourselves; to love those who love and care for us, including indicators of place attachment, empathy and love (Lawrence et al., 2004; Manzo and Devine-Wright, 2014; Perkins et al., 2010; Raymond et al., 2010).			•	•	•
• Being able to participate effectively in political choices that govern one's life, including indicators on level and quality of public participation in environmental management (Reed, 2008; Reed et al., 2009).	•	•	•	•	•
Social cohesion					
• Structural aspects: indicators of family and friendship ties; participation in organised associations; integration into the wider community (Cozens and Love, 2015; Stafford et al., 2003).				•	•
• Cognitive aspects: indicators of trust, attachment to neighbourhood, practical help, tolerance and respect (Mihaylov and Perkins, 2014; Uzzell et al., 2002).				•	

Examples of methods for assessing the indicators

- Public participatory GIS to assess experiential qualities (Brown et al., 2014; Laatikainen et al., 2015; Raymond et al., 2016b; Wang et al., 2015a).
- Ethnographic accounts of justice (Checker, 2011).
- Spatial analysis of the relationships between ecosystem services, park type and socio-economic profiles (Cohen et al., 2012; Hughey et al., 2016; Kabisch and Haase, 2014).
- Actor–Network Analysis (Ernstson, 2013; Ernstson et al., 2009).
- Historical analysis of the process of creating just or unjust environmental conditions (Schönach, 2014).
- Psychometric methods to assess place attachment, love or empathy (Lawrence et al., 2004; Perkins et al., 2010; Raymond et al., 2010), or the underlying structure of social cohesion (Comstock et al., 2010; de Vries et al., 2013; Stafford et al., 2003).
- Self-reporting instruments to assess indicators of literacy, numeracy and perceived levels of crime and safety.
- Grounded Theory (Strauss and Corbin, 1990) or Thematic Analysis (Braun and Clarke, 2006) techniques to explore the categories and sub-categories of meaning underpinning constructs like senses, imagination and thought related to NBS.

Potential success factors and limiting factors (including synergies and trade-offs)

- There is a potential trade-off between NBS design and environmental justice, particularly concerning issues of gentrification (Checker, 2011; Dooling, 2009; Wolch et al., 2014). Such a trade-off requires effective examination.
- Both trade-offs and synergies in ecosystems services can occur. Trade-offs are more likely for provisioning ecosystem services, when at least one of the stakeholders has a private interest in the natural resources available and at least one of the stakeholders acts at the local scale (Howe et al., 2014).
- Be aware of the varying perspectives of social justice that can affect both the policy approaches to justice issues and efforts to regulate identified issues (Kretsch and Kelemen, 2015). Future NBS research and practice needs to consider social justice from multiple perspectives.

Case example: Supporting social justice through the "Pocket Park" programme in London, UK.

The City of London Corporation owns and manages almost 11,000 acres of public green spaces in and around London. This includes wildlife habitats, nature reserves, sites of special scientific or historic interest, and outdoor spaces for sport, recreation and enjoyment (BOP Consulting, 2013). The Pocket Park programme, run by the Greater London Authority, aims to improve streets, squares, local parks, canal and riverside areas across the city and plans to deliver 100 new or improved areas of greenery within London's urban environment. One of the key aims is to promote collaboration between public bodies and local organisations, and to support volunteering, public participation and social cohesion. More than 60 projects are already supported, ranging from community orchards to Green Gyms to 'edible bus stops' (areas of green space located around London's transport network made up of flowers and vegetable plants) (Balfour and Allen, 2014). The Angel Community Garden, Enfield, London, is one Pocket Park initiative. It aims to develop a community food growing space within the new Angel Community Garden in order to provide opportunities for local people from multiple ethnicities to come together and help each other to run the space as a productive garden where fruit and vegetables can be grown (Project Dirt, 2013).

Challenge 9: Public Health and Well-being

The urban environment significantly affects the health and well-being of residents (Barton and Grant, 2006). NBS are supposed to improve the health and well-being of urban residents through the provision of ecosystem services by urban green spaces (Keniger et al., 2013). Many of the climate regulation ecosystem services address threats to environmental health posed by urbanization and climate change (Haase et al., 2014). Extreme weather events such as heat waves, exacerbated by the urban heat island (UHI) effect, cause premature death and illnesses (Basagaña et al., 2011; Xu et al., 2016). The UHI-effect is most significant in high-density built-up areas with impermeable surfaces and a low proportion of green space (Oke, 1973; Rizwan et al., 2008). Urban trees and vegetation provide climate regulation services as they reduce the UHI-effect through evapotranspiration, and shading and can thus prevent heat related morbidity, and mortality (Chen et al., 2014). NBS may reduce exposure to environmental pollution through mitigating the UHI (Alexandri and Jones, 2008; Bowler et al., 2010a) and reducing air pollution (Baró et al., 2014) and noise (Madureira et al., 2015).

Nature-based solutions can contribute to a range of positive psychological and physiological outcomes. Studies have shown the positive effects of urban green spaces on urban residents through psychological relaxation and stress relief (Roe et al., 2013; Ward Thompson et al., 2012) and enhanced opportunities for physical activity (Sugiyama and Ward Thompson, 2007). Studies have also identified positive health associations between distance to urban green spaces and potential health benefits, suggesting that being in proximity to urban green spaces (Maas et al., 2006) and viewing greenery (Dravigne et al., 2008; Ulrich, 1984; Ulrich, 2002) have positive health effects. Additional benefits include reduced depression (Bratman et al., 2015a) and improved mental health (Hartig et al., 2014; van den Berg et al., 2015; Vries et al., 2003); reduced cardiovascular morbidity and mortality (Gascon et al., 2016; Tamosiunas et al., 2014); improved pregnancy outcomes (Dadvand et al., 2012); and reduced obesity (Kim et al., 2014) and diabetes (Maas et al., 2009). Urban green space also provides opportunities for exploratory behaviour in children and improved functioning of the immune system (Kuo, 2015; Lynch et al., 2014).

However, urban green spaces can also be related to negative health outcomes, such as allergic reactions, or vector-borne diseases, because of increased exposure to allergenic pollen or increased disease vectors in urban green environments (Bai et al., 2013; Calaza-Martinez and Iglesias-Díaz, 2016; Cariñanos and Casares-Porcel, 2011). In addition, physical activity or play in green spaces may also be associated with increased risk of injuries particularly with children (Kendrick et al., 2005). These potential detrimental effects may be addressed through the adequate design, maintenance and management of urban green spaces and species selection (Lõhmus and Balbus, 2015).

Potential actions and expected impacts

Table 20 Potential public health and well-being actions and expected impacts

Potential actions	Expected impacts
• Distribute various types of urban green spaces as NBS across urban areas.	• Provision of health benefits and ecosystem services, which are available to people from different age groups and socio-economic backgrounds.
• Provide adequate urban planning and design mechanisms to ensure sufficient green space provision for positive health effects.	• A greater diversity and number of people having the opportunity to benefit from the positive health effects from urban green spaces.
• Design of urban green spaces, such as parks and playgrounds, should take in account the needs of children and the elderly while taking measures to minimize the risk of injuries.	• Improvement of opportunities for exploration by children and improvement of immune system already in children.
• Provide proper urban green space design, maintenance and recommendations to minimize trade-offs (allergenic pollen, transmission of vector-borne diseases).	• Decrease of detrimental effects of urban green spaces.

Examples of indicators

Table 21 Examples of public health and well-being indicators and their applicability at different geographic scales

Indicators	Measurement scale				
	mesoscale			microscale	
	Regional	Metropolitan	Urban	Street	Building/ Park
Psychological indicators (Relaxation and restoration, sense of place, exploratory behaviour, socializing).					
• Reduction in chronic stress and stress-related diseases measured through repeated salivary cortisol sampling (Roe et al., 2013; Ward Thompson et al., 2012) and hair cortisol (Honold et al., 2016); use cortisol slope and average cortisol levels as an indicator of chronic stress.			•	•	•
• Cognitive and social development in children: indicators related to improvement in behavioural development and symptoms of attention deficit/hyperactivity disorder (ADHD) related to green space use; questionnaire indicators on socio-demographic and household characteristics, the time spent playing in green and blue spaces, ADHD symptom criteria, such as emotional symptoms, inattention, conduct problems, hyperactivity/inattention, and peer relationship problems; and a strengths subscale for prosocial behaviour (Amoly et al., 2014).			•	•	•
• Mental health changes measured through Mental Well-being scales asking participants how they have felt over the previous four weeks in relation to a number of items (e.g., feeling relaxed, feeling useful), with responses rated on a 5-point scale from "none of the time" to "all of the time" (Roe et al., 2013).			•	•	•
Health indicators related to physical activity (Sports and leisure activities including e.g. walking, cycling).					

Indicators	Measurement scale				
	mesoscale			microscale	
	Regional	Metropolitan	Urban	Street	Building/ Park
• Number and share of people being physically active (min. 30 min 3 times per week).			•		
• Reduced percentage of obese people and children; reduced overall mortality and increased lifespan.			•		
• Reduced number of cardiovascular morbidity and mortality events (Tamosiunas et al., 2014).			•		
Health indicators related to ecosystem service provision (Buffering of noise and air pollution, reduced heat, exposure to microflora).					
• Reduced autoimmune diseases and allergies (potentially) (Kuo, 2015).			•		
• Reduced cardiovascular morbidity and mortality (Tamosiunas et al., 2014).			•		
• GIS related indicators: NDVI, proximity measures (green space of min. 2 ha within 300m, (Maas et al., 2006; Vries et al., 2003)), percentage of green space (Kabisch and Haase, 2014; van den Berg et al., 2010).	•	•	•	•	•

Examples of methods for assessing the indicators

- Self-assessment of perceived general health through on-site questionnaires or postal surveys using Likert scales (for assessment of stress-levels, relaxation, etc.), e.g. asking participants to rate how closely their mood matched certain statements of mood (Honold et al., 2012).
- Questionnaire surveys with parents and teachers, e.g. on strengths and difficulties (SDQ), and ADHD/DSM-IV (Amoly et al., 2014).
- Mobile electroencephalogram (EEG) system outdoors and EEG-based emotion recognition software for functional brain imaging to record any stress reduction as people walk into urban green spaces (Aspinall et al., 2015).
- Wearable sensors to demonstrate the effects of walking in a green space on brain activity (Aspinall et al., 2015).
- Spatial analysis of the relationships between accessibility, ecosystem services, park type and socio-economic profiles (Cohen et al., 2012; Hughey et al., 2016; Kabisch and Haase, 2014, Annerstedt van den Bosch 2016).
- Assessing effects of nature experiences through assignment of participants to particular exercises (e.g. walk in nature for a certain time) followed by psychological assessments and assessments of affective and cognitive functioning (Bratman et al., 2015a, 2015b).

Potential success factors and limiting factors (including synergies and trade-offs)

- A methodological combination of objective activity indicator measures such as cortisol measurements or brain imaging with questionnaire surveys that are based on self-perceived health and well-being assessments could be one option for obtaining transferable and objective results identifying the relation between green space and health (Kabisch et al., 2015).
- There are potential trade-offs between green space provision and negative health effects. Urban green spaces provide a number of health benefits, but there can be negative effects, for example, urban trees emit pollen which can cause allergic reactions in the population. Although there is a significant amount of existing research, there is a need for more in-depth studies quantifying exposure to pollen with

respect to potential confounding and characterizing mechanisms of age-specific adverse and beneficial health effects. Estimating allergenicity of an urban green space may be done through the allergenicity index, which is calculated using allergenic potential, pollination characteristics, tree size and number of individuals per species in a green space (Cariñanos et al., 2014).

- Evidence is inconsistent regarding the regulation potential of urban green space to reduce air pollution levels. Some studies show significant effects (Baró et al., 2014; Nowak et al., 2013), while others show no effect (Setälä et al., 2013) or even worsened pollution levels under street tree canopies (Jin et al., 2014) with related severe health effects.
- Linkages between residential proximity to a green space and health improvements in some studies were inconclusive (Amoly et al., 2014) or weak because of a difficult and complex causal relationship which is hard to cover in causal analyses (Lee and Maheswaran, 2011).

Case example: Green space and public health and well-being in Kaunas City, Lithuania

Tamosiunas et al. (2014) assessed the potential relationships between distance and use of urban green spaces and prevalence of cardiovascular diseases and its risk factors in Kaunas City. The authors used a random sample of more than 5,000 people, aged 45-72 years, screened at the end of the last decade. Multivariate regression models identified no significant association between objectively measured distance to urban green and cardiovascular risk factors and the prevalence of common chronic non-communicable diseases, such as stroke or diabetes mellitus. However, the prevalence of self-reported or measured lifestyle-related and biological risk factors, such as smoking or obesity, and the prevalence of diabetes mellitus and cardiovascular risk factors was significantly lower among park users than among non-users. The authors plead for policies addressing public health and promoting healthy lifestyles in cities. They suggest a balanced provision of green spaces on the neighborhood scale, which should take into consideration population density, land use and other predictors of good health in urban environments.

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Challenge 10: Potential for Economic Opportunities and Green Jobs

Research shows that increasing the green areas in the urban environment has considerable co-benefits through, for example, increased real estate values, positive health effects, improved water management or recreational services (BOP Consulting, 2013; Elmqvist et al., 2015; McConnell and Walls, 2005; TEEB, 2011; van den Berg et al., 2015), indicating that NBS strategies can cost-effectively address a diverse set of environmental problems in urban areas. Thus as well as contributing to meeting direct challenges, NBS generate co-benefits (Pearce et al., 2002) that can save money at household and government level and create economic opportunities for "Green businesses" (OECD, 2013). Furthermore, the introduction of NBS offers an opportunity for the creation of "Green-Collar Jobs", from low-skill, entry-level positions to high-skill, higher-paid jobs (Apollo Alliance, 2008; Falxa-Raymond et al., 2013).

Potential actions and expected impacts

Table 22 Potential actions for supporting economic opportunities and green jobs and their expected impacts

Potential actions	Expected impacts
• Encourage methods to transfer the benefits of common goods provided by NBS to the initiators of NBS, e.g. through tax reductions or subsidies (Meulen et al., 2013).	• Increased willingness to invest as more of the co-benefits accrue to the initiator. • Increased competitive advantage for cities applying NBS measures (OECD, 2008). • Net additional jobs in the green sector fuelled by new green investments.
• Support vocational training programs to enhance skills in the design and delivery of NBS measures (Falxa-Raymond et al., 2013).	• Increased knowledge on NBS and the appropriate implementation of the NBS measures. • Individual earnings uplift arising from skills enhancement in the design and implementation of NBS.
• Increase knowledge and awareness on NBS in the urban environment for stakeholders and policy makers.	• Increase in implementation of NBS and associated employment as initiators become more familiar with NBS solutions. • Policy makers will develop an active approach towards NBS application within the public domain and infrastructure. • Policy makers will develop an active approach towards NBS application and possible provision of (co)financing arrangements for private properties. • Increased knowledge base, as more implementation of NBS will increase their application under diverse circumstances.
• Develop online NBS impact calculation tools.	• Increased awareness of NBS solutions and their effectiveness and (co)benefits. • Increased knowledge base on values of NBS impacts.
• Restore or plant green spaces or other NBS.	• Creation of green jobs relating to construction and maintenance of NBS (Saraev, 2012). • Benefits for work productivity including reduced absenteeism (Saraev, 2012). • Increased commercial (Gensler, 2011) and domestic property prices (Eftec, 2013; Forestry Commission, 2005; Lutttick, 2000). • Attraction of businesses (Eftec, 2013). • Increased social interaction (see Challenge 8).

Examples of indicators

Table 23 Examples of economic opportunity and green job indicators, and their applicability at different geographic scales

Indicators	Measurement scale				
	mesoscale			microscale	
	Regional	Metropolitan	Urban	Street	Building
• Number of subsidies or tax reductions applied for (private) NBS measures (Meulen et al., 2013).	•	•	•	•	•
• Number of jobs created (Forestry Commission, 2005); gross value added (Forestry Commission, 2005).	•	•	•		
• Change in mean or median land and property prices (Forestry Commission, 2005).	•	•	•	•	•
• New businesses attracted and additional business rates (Eftec, 2013).	•	•	•		
• Resource efficiency in the urban system (CO2 emissions per capita, CO2 emissions for transportation per capita, etc.) (OECD, 2013).	•	•	•		
• Public-sector cost per net additional job (Tyler et al., 2013).	•	•	•		
• Net additional positive outcomes into employment (Tyler et al., 2013).	•	•	•		
• Net additional jobs (Tyler et al., 2013) in the green sector enabled by NBS projects.	•	•	•		
• Gross value added per employees based on full-time equivalent jobs (Tyler et al., 2013) in the green sector.	•	•	•		
• Production benefit: earnings uplift arising from skills enhancement (Tyler et al., 2013) in the design and implementation of NBS.	•	•	•		
• Consumption benefits: property betterment and visual amenity enhancement (Tyler et al., 2013) resulting from NBS.	•	•	•		

Examples of methods for assessing the indicators

- Cost Effectiveness Assessments (CEA), assessing the performance (non-monetary, single outcome) of the measures against their costs (Pearce et al., 2002).
- Multi-criteria Analysis (MCA), assessing the performance (non-monetary, multiple outcomes) of the measures through public or expert opinion (Pearce et al., 2002).
- Social Costs and Benefits Approach (SCBA), analysing the monetised costs and benefits from the effects of the measures discounted over time (Pearce et al., 2002; Romijn and Renes, 2013).
- GIS/Satellite/aerial imagery inventories (e.g. for green roofs, parks, public gardens) to assess impacts of measures (e.g. on health, real estate values).
- Land use changes from planning documents and maps (urban regeneration plans, including more green spaces) to assess ambitions and plans.

Potential success factors and limiting factors (including synergies and trade-offs)

- An analysis of the synergies and conflicts in natural capital investments shows a significantly greater number of synergies, and potential synergies (e.g. water and temperature management), than conflicts (e.g. allocation of scarce available space) (Eftec, 2013). The synergies can be not only economic (e.g. through reduced management and investment costs, or economies of scale), but also include social (e.g. social/community interaction in parks; educational opportunities) and environmental (e.g. increased biodiversity) benefits.

- Trade-offs or conflicts can occur through competition for space or other resources, and socio-political conflicts can occur due to uneven costs and benefits (Eftec, 2013).
- Additional research is needed to quantify benefits and standardize indicators and data collection methods to better assess effectiveness of NBS; for example, impacts of green roofs through online calculators (Berardi et al., 2014).
- There is a need to identify and encourage policies for the restoration of planting of green space.
- Little research has investigated the effects of working professionally in urban natural resources management (Falxa-Raymond et al., 2013).
- Methods for capturing the monetised multiple economic benefits of NBS are lacking.

Case example: Green roofs and decoupling of rainwater drainage from houses in the Netherlands

Green roofs and decoupling of rainwater drainage from (private) houses can be particularly effective actions for water retention, limiting stormwater drainage in the urban environment. Furthermore, these measures can have positive benefits through a number of additional effects, such as decreasing the urban heat island effect and reducing household energy consumption through the insulating effect of green roofs (Gehrels et al., 2016; Pearce et al., 2002). However, not all these benefits accrue to the same stakeholder, making investments from a single initiator problematic (Gehrels et al., 2016; Meulen et al., 2013). A number of municipalities and water authorities in the Netherlands have initiated subsidies to households for NBS measures like green roofs and decoupling of rainwater evacuation from residential homes, which limit stormwater drainage into the sewer system and create substantial co-benefits for municipalities and wastewater treatment facilities. Programs providing a subsidy of up to 50 % of the investment costs achieved a take-up of 80–95 % by households in the participating street, while few households installed these measures without the subsidies, as the direct benefits are insufficient to cover the investment costs (Meulen et al., 2013).

Application Guide for the Assessment of the Effectiveness of NBS Projects

Background

This short application guide is intended to provide inspiration and indications for guidance for researchers, practitioners and administrators during the entire process of designing, planning, assessing and monitoring projects based on NBS. Addressing strategies for ex-ante and ex-post assessment of potential costs and benefits and valuation and monitoring of the actual efficiency of NBS, this application guide is targeted at different phases of a policy cycle, including the assessment of local needs, evaluation of alternative solutions and monitoring of implemented measures. It is largely based on the findings of the short scoping review of the literature presented in the earlier sections of this report. The guide starts with recommendations on how to select and apply NBS indicators and methods. It then provides a roadmap for the assessment of NBS impacts across the 10 climate resilience challenges, with a focus on the key knowledge gaps, and future directions for NBS research and practice.

Types of NBS indicators and methods

Given that NBS seek to address societal challenges, they need, by definition, to address economic, environmental and social challenges. There are a range of potential actions that can be taken and indicators are an important means of assessing the potential performance and the actual effectiveness of particular NBS actions. The EWG has identified a selection of quantitative and qualitative indicators that can be used for such assessments within and across the various climate resilience challenges presented in this report. These lists present examples of some of the most important indicators which can be used for assessing the key impacts of NBS related to the different challenges. They are thus indicative and far from being exhaustive.

The selection of appropriate indicator(s) will depend on a number of factors including:

- Objective of the action — which challenge(s) it is seeking to address;
- Type of action — all NBS will involve some element of biodiversity, but will differ in their attributes and thus appropriate methods for measurement;
- Potential expected impacts, both direct and indirect, and both positive (synergies) and negative (trade-offs or disservices);
- Resources and skills available for measurement of the impacts;
- Scale of analysis, which influences the availability and relevance of data for specific indicators.

Once the overarching aim of a project has been established, decisions will need to be made about:

- Which components of each challenge are relevant and will be addressed;
- Which alternative solutions could address each of the challenges identified;
- The geographical and temporal scale of the action and its effect;
- Which indicator(s) will be appropriate to measure the effectiveness of individual actions in addressing each challenge;
- Which methods are available, suitable and feasible for the measurement of the indicators;
- What baseline will be used, considering the scale, and including measurements that should be taken prior to the commencement of any action, so that effectiveness can be measured;
- How to identify interactions between actions and how to maximise opportunities presented by co-benefits (synergies) and minimise trade-offs between conflicting desired effects.

These aspects are developed and described below.

Spatial scale of NBS and impacts from NBS

The spatial scale over which impacts from NBS can be assessed varies with the type of NBS adopted, the scale at which it is implemented and the kind of impact considered: while the capacity of vegetation on a single green roof or a bioretention structure to store rainwater can be measured at the micro scale of the single building or structure, benefits in terms of reduced run-off and, as a consequence, reduced flood risk, can be recorded at micro (street) or meso (urban) scale (Challenges 1 and 2). Similarly, the impact of NBS on urban temperatures can be measured at the micro scale of a single building and translated directly into economic benefits from reduced energy demand for heating and cooling at household level (Challenge 4), while the carbon emissions accounting from such an action occurs at the meso (urban, regional) and macro (national) levels.

The scale of environmental impacts from NBS in many cases depends on the physical dynamics acting at the micro (street/neighbourhood) or even meso (metropolitan, urban) level: water flows, heat and pollutant fluxes need to be considered when environmental impacts from single measures (e.g. green roofs or pocket parks) are up-scaled to the street, urban or metropolitan scale. For example, for measures aiming at reducing urban temperatures, the impacts from enhanced evapotranspiration and increased shading will depend on the dimensions of the NBS implemented, but also on heat fluxes determined by the street or urban morphology (Challenges 1, 4, 5 and 9).

In many cases, the measurement of impacts may not be reasonable or even feasible at an urban scale because the change caused by a single measure is too small; while the amount of pollutants captured by vegetation may be important at the micro scale, a single project will hardly affect the quantity of pollutants at the meso (urban) level. The same holds for water quality, the urban heat island effect and the carbon storage capacity, as the impacts of spatially limited individual NBS projects (or actions) may be very small, but in aggregate they can make a difference.

Social impacts can be assessed mostly at the neighbourhood (street) level, paying attention to the aspect of accessibility. For ecological connectivity, the accessibility of structures created as NBS, for example green areas, is not necessarily identical to physical proximity, due to the existence of different kinds of barriers to movement (Challenges 4, 8, 9). However, there is also the potential for interactions in social impacts across geographic scales, which requires further consideration in future NBS studies.

Temporal scale of NBS

There is little information available in the literature on the time for individual NBS actions to become fully effective, thus three broad categories have been selected (Table 24): short (within 5 years), medium (5-10 years) and long-term (over 10 years). The temporal scale over which a NBS becomes effective varies, so some indicators, such as changes in salinity (Challenge 2) or quantitative changes in the percentage of accessible public green space per capita (Challenge 4), can alter over the short-term, while the effectiveness of others may take longer to be realised. For example, air quality may change more gradually (Challenge 5) and while the presence of or access to green space can lead to immediate behavioural changes, often it takes time to change habits relating to exercise and thus derive the health benefits (Challenge 9) or build up attachments to places (Challenge 8). Therefore, while many NBS actions will start to have an effect once implemented, there may be a time gap between this initial effect and the point at which they become fully effective. The timing and maintenance of effectiveness can also depend on the quality of the habitat, and assessment of timing assumes that the nature-based components become and remain in a favourable condition.

The temporal scale can also be affected by the type of the NBS components. For example, given that NBS involve the use and enhancement of nature, CO_2 capture and carbon sequestration (Challenges 1, 5) should be enhanced, but the amount and timing will depend on the ecosystem involved. Given the variety of factors that can affect the temporal scale of the effectiveness of individual NBS actions, any assessment should consider the length of time for particular actions to become effective in relation to the challenge to be addressed and its urgency.

Methods

Single impacts

The assessment of environmental impacts will depend primarily on the measurement and description of physical parameters, such as temperature, pollution concentration or morphological characteristics. These measures are, in many cases, not available or difficult and expensive to undertake. Similarly, some of the health indicators require specialist equipment to measure cortisol levels (Challenge 9). The use of models can be a strategy for assessing potential impacts based on parameters measured in other contexts, as, for example, in the iTree Eco model, which provides a database with values on ecosystem services produced by trees species in different climatic zones.

Aggregation of impacts

In order to support decisions and choices between different options for NBS or alternative investments, the costs and benefits of each option need to be aggregated. The most common approach to this aggregation is based on economic (monetary) assessment methods which aggregate all monetary costs and expected benefits of the investment.

While a CBA approach normally considers the costs and benefits directly connected to single (or a group of) investors (e.g. a local authority or utility), the Social Costs and Benefits Approach (SCBA) includes wider societal costs and benefits in the assessment, such as tax revenues, subsidies, increased real estate values, etc. Also, a wealth of experience has been developed for the assessment of non-economic values in monetary terms for CBA or SCBA assessments, either using proxies for the values (e.g. the increased quality of life in an urban area will easily translate into increasing real estate prices using the hedonic pricing approach) or using approaches that translate individual preferences into monetary values (e.g. willingness to pay).

Many of the environmental and social benefits and costs connected to the impacts of NBS actions are measured in terms of physical parameters or qualitative judgements of individual and aggregated preferences, which can only partly be translated into monetary terms (e.g. pollution-related health effects) and are thus difficult to aggregate. Consequently, such benefits are often excluded from NBS impact assessments. Researchers and practitioners, therefore, need to recognise the importance of a range of assessment processes including qualification, quantification, aggregation and standardisation. Assessment strategies which allow for assessments based on mixed methods can support the consideration of different scales and measures. In particular, methods based on multi-criteria analysis allow for an assessment of the performance of alternative solutions built on group preferences. Considering the performance of solutions with regard to different potential benefits, both qualitative and quantitative values can be used for the assessment. Multi-criteria analysis allows for the representation of different outcomes of the assessment process according to different group (or individual) preferences. Rather than producing a single result indicating the “optimal” solution, these approaches allow for visualising the impact of different preferences on the assessment results. There is a need for participatory tools and processes that consider diverging values and preferences, contributing to more transparent processes for deliberation and decision-making.

Long-term measurement and monitoring

Considering the great range of uncertainty connected to the behaviour of NBS in complex urban systems, the continuous monitoring of impacts from NBS represents an essential element for keeping NBS efficient, as impacts unfold on longer time frames and external conditions may change, for instance in relation to climatic change. Also, monitoring can provide new insights into the functioning of NBS and activates a learning process which can help improve subsequent implementations.

Thresholds

A large variety of thresholds for specific indicators are present in the legislation and regulations at various spatial and administrative scales. Thresholds related to NBS efficiency should be considered in relation to the local context, which is better suited for defining them, especially when no legal standards exist. From the perspective of adaptive strategies, the definition of "critical thresholds" with respect to key indicators can help identify situations in which changes in the design of NBS or new solutions are needed.

Interactions between NBS actions, and synergies and trade-offs within and across NBS projects

Many of the NBS actions, while having a direct effect on a specific challenge, may have indirect effects on other aspects of the same or different challenges. Table 25 provides examples of how selected indicators may interact with other challenges, although once again issues of scale, implementation and local context may be important. For example, property prices (Challenge 10) may have positive or negative effects on social justice and equity, depending on location. Table 25 also recognises that some of these interactions represent co-benefits or synergies across challenges, while others can have trade-offs.

Which types of expertise are required to make assessments and comparisons?

Assessing the effectiveness of NBS actions is a complex process requiring (i) the engagement of a range of different actors including academics, practitioners and businesses, (ii) a range of disciplines and transdisciplinary working, and (iii) the employment of a variety of different indicators and methods, in order that the economic, environmental and social challenges can each be addressed.

Comparison across NBS projects could be undertaken by, for example, the use of some common indicators, such that evidence and knowledge is built up on the effectiveness of particular actions under different contexts. NBS projects also could be linked, such that certain actions which may have already been take in one case study are replicated and tested further in a different context in another project.

How to ensure NBS assessments are effective over the long-term

Some NBS actions, as indicated, will unfold their full benefits (and costs) only over a longer period of time, when the restored natural flows and functions are fully operational. Especially in the context of financed projects for the implementation of NBS it is thus necessary to plan for monitoring beyond the end of the action. This can involve institutional actors extending and adapting their monitoring programmes, but also non-academic project partners and local communities designing strategies for citizen science activities, NGOs or local statutory organisations.

Summary of the associations among indicators, methods and scale

Table 24 summarises the different aspects of indicator and methods selection and application discussed above. By way of example, it is shown that there is a range of indicators for Challenge 4, and they are each applicable at different geographic and temporal scales. Similarly, a range of indicators can be used to assess the impact of NBS that address cross-cutting challenges like Challenge 8 (social justice and social cohesion). For additional examples refer to Appendix 1.

Examples of the possible range of co-benefits and costs as identified in the 10 challenges are given in Table 25. For example, flood peak reduction actions are likely to have co-benefits for coastal resilience and green space management, but also for social justice (lower income households are more vulnerable to flood risk and often also more exposed, e.g., Brown and Damery, 2002). There are also opportunities for urban regeneration and social justice and social cohesion from actions aimed at reducing flood peaks. In contrast, increases in property prices stemming from actions to improve economic opportunities and green jobs in urban areas may adversely affect social justice and social cohesion by displacing groups of socio-economically disadvantaged residents. Nevertheless, as potential costs, benefits and trade-offs need to be assessed in the specific local context, this table can only indicate some of the interactions between the challenges, including opportunities to build synergies.

Table 24 Examples of associations between indicators and methods of assessment, and their applicability at different geographic and temporal scales

Challenge	Indicator description	Type of indicator (which determines the way it can be used for assessments)	Unit of measurement	Examples of method(s) of assessment for indicator	Geographic Scale					Temporal scale		
					Region	Metro politan	Urban	Street	Building	Short	Medium	Long
Ch1	Reduced energy demand for heating and cooling	Environmental (chemical) benefit	CO_2 emissions reduced	With reference to a baseline situation, the energy not consumed can be accounted for as a reduction of CO_2 Emissions	•	•	•	•	•	•	•	
Ch1	Net carbon sequestration by urban forests (including GHG emissions from maintenance activities)	Environmental (chemical)	t C per ha /year	Numerical methods calculating or estimating the interactions between vegetation and pollutants at the micro scale; allometric equations that predict vegetation growth; Forest Inventory Analysis			•			<	•	•
Ch5	Annual amount of pollutants captured by vegetation	Environmental (chemical)	t pollutant per ha /year	"Tiwary method", map air purification using spatially-explicit data on ecosystem types and characteristics (particularly LAI), and pollution distribution; Forest Inventory Analysis	•	•	•			<	•	•
Ch8	Security against violent assault, including indicators of crime by time of day	Social (physiological)	No of cases / year	Statistics and perceived levels of crime and safety.				•	•	•		
Ch7	Being able to participate effectively in political choices that govern one's life, including indicators on level and quality of public participation	Social	Number of connections /threshold for the definition of sufficient levels of connections	Actor-Network Analysis to better understand how different stakeholders can bias management towards certain ecosystem services	•	•	•	•	•	<	•	

< in some cases the indicator and/or method can be applied at this scale

Table 25 Examples for indicators of potential co-benefits and negative impacts across the challenges

Ch	Indicators	Ch 1 Climate Resilience	Ch 2 Water	Ch 3 Coastal Resilience	Ch 4 Green space	Ch 5 Air quality	Ch 6 Urban regeneration	Ch 7 Particip planning & governance	Ch 8 Social justice & cohesion	Ch 9 Public health & well-being	Ch 10 Economic opps & green jobs
Ch 1	Carbon sequestration	*	+	**O**	+	+	+	**O**	**O**	**O**	
Ch 1	Temperature reduction	*			+	+				+	
Ch 2	Flood peak reduction		*	+	+		**O**	**O**	**O**	+	+
Ch 2	Increasing ground water quality		*		+			**O**	**O**		
Ch 3	Erosion protection			*	+		**O**	**O**	**O**		+
Ch 3	Enhanced recreation			*	+			**O**		+	**O**
Ch 4	% of citizens living within a given distance from accessible, public green space		**O**		*	+	**O**	**O**	+	+	+
Ch 4	Increased species richness				*	**O**		**O**		**O**	+
Ch 5	Amount of pollutants captured by vegetation		+		+	*		**O**	**O**	+/-	+
Ch 5	Premature deaths and hospital admissions averted				+	*	+		**O**	+	**O**
Ch 6	Urban food production		**O**		+		*	**O**	**O**	+	+
Ch 6	Increased ecological connectivity				+	**O**	*	**O**		**O**	**O**
Ch 6	Energy efficiency: building layout and design		**O**		+		*	**O**	**O**	+	+
Ch 7	Legitimacy of knowledge in participatory processes			+	+	+		*	*	**O**	**O**
Ch 7	Social values for urban ecosystems and biodiversity	+					**O**	*	*	**O**	
Ch 8	Being able to move freely and safely from place to place				+		**O**	**O**	*	**O**	**O**
Ch 8	Attachment to neighbourhood				**O**				*	+	
Ch 9	Reduction in chronic stress and stress-related diseases				**O**		**O**	**O**	**O**	*	**O**
Ch 9	Reduced percentage of obese people				**O**			**O**		*	**O**
Ch 10	Number of jobs created				+				+	+	*
Ch 10	Increase in property prices				+		-		+/-		*

Key: Ch = challenge; * Main challenge addressed; + Co-benefits that will follow; **O** Opportunities that could be taken; - Potentially negative impacts or disservices

Roadmap for the assessment of NBS impacts

Research and practice into NBS to support climate resilience in urban areas is still in its infancy. For this reason, there are many knowledge gaps and associated directions for research and practice. Here some of the major gaps and directions stemming from this quick scoping review of the literature are presented. The list of knowledge gaps in Table 26 is designed to guide future research and practice and, therefore, should be seen as an opportunity for researchers and practitioners from a range of disciplinary backgrounds to work together on NBS. This list has not been prioritised because the relative importance of each gap is likely to vary across different types of NBS and urban contexts in Europe and beyond.

Knowledge gaps

Table 26 Summary of knowledge gaps related to the assessment of NBS impacts

Area	Short description	Explanation
Actions and impacts	Design NBS actions which are cost effective and give rise to a range of social and environmental benefits.	Researchers and practitioners have good understanding of the environmental impacts of NBS, but it remains unclear as to whether specific actions are cost effective and give rise to a range of benefits. This gap points to the need to better understand the interface between environmental, economic and social dimensions of NBS. Also, the impacts stemming from socio-cultural and ecosystem interactions require further consideration. For example, how NBS contribute to social justice, social capital and social cohesion, and the inter-economic and inter-cultural partnerships necessary to address these climate resilience challenges.
	Promote the positive impacts of NBS which are not likely to have negative impacts in other challenge areas.	While substantial research has investigated the potential for synergies and trade-offs in ecosystem service flows related to green space management, the potential for positive and negative impacts are rarely considered across challenge sets.
	Relate different elements of environmental and social impact to ecosystem service stocks and flows.	NBS take into account a broad array of environmental, socio-economic and socio-cultural impacts. How to relate the ecosystem service framework to a range of social and economic impacts within and across climate resilience challenge areas (as noted here) remains an important knowledge gap.
	Adapt the monitoring of the effectiveness of NBS over time and readapt the NBS management accordingly.	NBS are usually implemented to be part of the urban environment for a long time. In several cases, their effectiveness is going to change, because of the growth or the aging of the NBS itself, necessitating changes to the accounting and monitoring methodology.
Indicators	Develop indicators that cross-cut challenges and are applicable within and across geographic scales.	This report has shown that indicators are context-sensitive. Some indicators are pertinent to one scale whereas others are pertinent across scales. However, few empirical studies have assessed the sensitivity of indicators across geographic scales, or the relevance of indicators across different climate resilience challenges.
	Assess the validity and reliability of indicators across space and time.	Questions associated with the internal and external validity of indicators across space and time and their reliability in the face of different socio-ecological pressures have not been considered.
	Develop specific ecological indicators and methods to relate ecosystem status to ecosystem service supply.	Identify ways in which the supply of environmental, social, and cultural services can be related to specific aspects of ecosystems.

Area	Short description	Explanation
	Compare standardised and non-standardised indicators.	While it was attempted to standardise all indicators in this report, it was not possible to standardise all, particularly those in the social domain.
Methods	Assess the adaptability and flexibility of NBS actions to new stressors, such as climate change.	Existing NBS actions and impacts are often assessed under current conditions, without considering the projected impacts, such as climate change and biodiversity loss.
	Evaluate the links between NBS impacts and adaptation to climate change.	There is an absence of methods for translating regional level climate information to the local level. Existing methods of NBS assessment often do not consider individual and community capacity to adapt to climate change. For example, extreme climate events warning systems often do not consider the thermoregulation profile of local residents, and their adaptation to daily climatic variability.
	Assess changes in environmental impacts resulting from NBS interventions across existing, modified and new natural areas.	It is often assumed that NBS provide for the establishment of new nature, but the connectivity among existing, modified and new natural areas is often overlooked.
	Integrate climate, social, demographic and economic trends and patterns into NBS impact assessments.	NBS impacts need to be considered within a wider context of climate, social, demographic and economic trends and patterns. Few methods link primary data on NBS impacts with secondary data on such trends or vice versa.
	Balance qualitative and quantitative aspects in NBS impact assessments.	Interdisciplinary, mixed-method research designs that balance the need for qualitative and quantitative assessment of NBS impacts are missing from the NBS literature. Assessments which balance these are crucial to appreciating and understanding the complex linkages between elements of the socio-economic, socio-cultural systems and ecosystems.
Governance, communication and engagement	Develop stakeholder engagement and governance processes to actively engage academics, practitioners, policy makers, NGOs and local residents in the design and assessment of NBS.	NBS impact assessments often draw upon expert knowledge embedded in western science traditions. However, there are a range of other types of knowledge (e.g., indigenous, local, tacit) which require consideration in NBS impact assessments. The relationship between different types and systems of knowledge are an important gap in current research and practice.
	Continuously monitor urban climate systems and tailor NBS to different types of stakeholders at the local level.	While there is substantial knowledge and information on urban climate systems, there is an important knowledge gap concerning how to communicate NBS and climate information (e.g. thermal comfort data) to a range of local stakeholders in a meaningful way.
	Improve literacy about global NBS and climate change impacts at the local scale, to motivate resident involvement in NBS implementation.	How to translate complex knowledge and information about climate change and NBS into meaningful implications at the individual level is often missing from current scholarly discussions. Emphasis is being placed on the design, implementation and monitoring of NBS by planners, researchers and decision makers. Local residents are an important NBS stakeholder, and new techniques are required to motivate their involvement in NBS initiatives.

Future directions for research and practice

In this section, some of the future directions for NBS research and practice are summarised (Table 27). The guidance offered here is based on the aforementioned knowledge gaps.

Table 27 Summary of future directions for NBS research and practice

Area	Research or practice direction
Actions and impacts	Assess the synergies and trade-offs of NBS for specific objectives within and across climate resilience challenges. Take note of the full range of synergies and trade-offs across socio-economic, socio-cultural, climate, biodiversity and ecosystem domains using both ecosystem service assessments and other forms of environmental and social science enquiry.
	Identify and assess the co-benefits and costs of NBS within and across climate resilience challenges, also taking into account of the inter-relationships between elements of the socio-economic, socio-cultural, biodiversity and ecosystems. This includes elements of inter-economic partnership between economy and biocultural diversity, intercultural partnership between biocultural diversity and ecology, interspecies partnership between ecology and social justice and social cohesion and inter-generational partnership between justice/cohesion and economy (see Williams and Brown, 2012 for further information).
	Model and quantify the potential for positive and negative NBS impacts within and across challenge sets, and across different temporal and geographic scales, including how their effectiveness changes over time.
	Focus on the co-production of NBS to move beyond a narrow understanding of the instrumental benefits of the ecosystem for human well-being to a more holistic understanding of the role of NBS in restoring and managing elements of socio-ecological systems.
	Develop, together with the NBS plan, an adaptable management strategy which takes into account the changes over time of the implemented NBS, the society and the urban ecosystem.
	Make a socio-spatial assessment of residents who benefit the most and the least from NBS projects to address possible unforeseen or unexpected disservices, also considering social exclusion or inequalities.
Indicators	Assess the relevance and sensitivity of indicators across geographic scales in order to inform the upscaling of NBS.
	Develop multi-metric indicators able to assess the potential impact and co-benefits of NBS on multiple challenges either from the quantitative and/or qualitative perspective possibly to be also used as proxies for overall change in resilience (environmental, social and economic).
	Where NBS integrate natural and artificial tools, develop indicators of how the living component contributes to enhance the function and resilience of the built systems and vice versa.
	Undertake longitudinal studies in order to assess the internal and external validity of indicators across time, and their reliability in the face of different socio-ecological pressures, such as climate change and migration.
	Where possible adopt standardised indicators per unit of space and/or unit of time which can be easily compared among different projects and different case studies, as well as being used to up-scale impacts over wider areas and/or different time scales.
	Combine indicator systems, whenever possible, to map and assess co-benefits of NBS projects.
	Consider combining qualitative indicators with quantitative indicators to assess trade-offs across challenges of NBS projects.
	Consider elements of quantity and quality in NBS assessments by drawing upon both exploratory and explanatory indicators. Consider the external validity of indicators across climate resilience challenges and cross-cultural contexts.
	Identify the relation between thresholds imposed by legislation and regulations and the performance of indicators related to NBS development projects.

Methods	Develop new modelling techniques for assessing the projected impacts of NBS across different challenge scenarios, and across time.
	Create models able to predict the status of NBS and their expected impacts in the future (long-term) taking into account also the changes of the surrounding environment.
	Develop new methods to bridge qualitative and quantitative indicators and their valuation that can be transferable across different urban contexts.
	Develop new connectivity analysis techniques to understand how NBS contribute to the conservation and enhancement of existing, modified and new natural areas.
	Employ interdisciplinary, mixed-methods research designs to explore and explain NBS impacts within and across climate resilience challenges.
	Using the urban-rural gradient as a unique tool to test NBS implementation across different environmental, socio-cultural conditions, as well as to test their effectiveness on improving the initial degraded status.
Governance, communication and engagement	Develop new participatory planning and governance processes in order to engage multiple stakeholders in NBS assessment and to weave multiple types and systems of knowledge into NBS assessments.
	Develop new participatory planning and governance processes to bring to the surface perceptions, values and elements of ecological memory that can enable the creation of a sense of place through a NBS project in neighbourhoods and city areas.
	Create multi-stakeholder international networks on NBS planning and implementation with the scope of transferring successful approaches from one country to another or from one case study to a wider community.
	Develop new education and learning initiatives for promoting literacy about NBS impacts and climate resilience among citizens.
	Introduce specific thresholds in international or national legislation about the requested investment in NBS for climate resilience in urban areas.

Conclusions

The following conclusions can be drawn from this report:

1) Each climate resilience challenge area can be addressed by multiple individual actions, and indicators can be used to assess the effectiveness of individual actions in addressing each climate resilience challenge. However, there is potential for interactions between NBS actions which require consideration in NBS assessments;
2) Indicators for assessing specific types of NBS impacts can be relevant to multiple climate resilience challenges. It is, therefore, important to assess the impacts of NBS across aspects of multiple systems, including socio-economic, socio-cultural and ecosystems, although geographic and temporal scale may be relevant to the interactions;
3) The applicability of indicators can vary across geographic scales, highlighting the importance of considering regional, metropolitan, urban, street/neighbourhood and building impacts separately;
4) There is a need for assessing the impacts of NBS over the short, medium and long-term, and thus mechanisms are needed for monitoring NBS effectiveness beyond the end of the project;
5) Synergies and trade-offs can be associated with NBS impacts, including across elements of the ecosystem and socio-cultural system. NBS impacts are, therefore, likely to be multi-directional and complex;
6) Investment in NBS can maximize the benefits for provision of environmental, socio-cultural and economic services if multiple challenge areas are considered concurrently and the different stakeholders are involved in the planning and implementation process.

Each of these elements needs to be considered prior to implementing NBS in relation to the specific challenges of the area under investigation and in addition to the evaluation stage.

Furthermore, important areas for future research and practice have been identified. The geographic and temporal dimensions of NBS impacts remain poorly considered in the peer-reviewed and grey literature and are important directions for future research. While substantial attention has been dedicated to assessing the environmental impacts of NBS, little research and practice has assessed the potential for co-benefits, synergies and trade-offs across elements of the socio-cultural and socio-economic systems and ecosystems, as well across different attributes of biodiversity and climate. Interdisciplinary techniques are, therefore, required to address these gaps. Co-benefit assessments will require the development of new tools for assessing synergies and trade-offs outside of the ecosystem services domain, and a commitment to managing ecological and social complexity by drawing on knowledge co-production processes that engage multiple types and systems of knowledge.

Despite this report mainly addressing the issue of evaluating the effectiveness of NBS, the importance of including the concept of NBS in the strategic and planning documents at the international, national or regional level is strongly recognized. By adopting an appropriate strategy for NBS, different targets could be set up, first for promoting the use of NBS across Europe and afterwards for their implementation via existing legal, policy and financial instruments.

In fact, how to integrate NBS impact assessment with NBS implementation remains another important research gap. Impact assessment and implementation have traditionally occurred separately, but co-production processes are needed for bridging these two fields. This may involve considering the specific types of capitals (e.g., natural, built, financial), capabilities and agency that are required to implement specific types of NBS alongside the environmental, social and economic co-benefits of NBS.

References

Adger, W.N., Arnell, N.W., Tompkins, E.L., 2005. Successful adaptation to climate change across scales. Glob. Environ. Chang. 15, 77–86. doi:10.1016/j.gloenvcha.2004.12.005

Ajuntament de Barcelona, 2009. Barcelona, a city committed to the environment. Barcelona Environmental Report. http://lameva.barcelona.cat/barcelonasostenible/sites/default/files/documents-i-mes/document/293/eng-environmentalreport.pdf

Ajuntament de Barcelona, 2013. Barcelona green infrastructure and biodiversity plan 2020. http://ajuntament.barcelona.cat/ecologiaurbana/sites/default/files/Barcelona%20green%20infrastructure%20and%20biodiversity%20plan%202020.pdf

Akbari, H., 2002. Shade trees reduce building energy use and CO_2 emissions from power plants. Environ. Pollut. 116, 119 – 126.

Akbari, H., Cartalis, C., Kolokotsa, D., Muscio, A., Pisello, A.L., Rossi, F., Santamouris, M., Synnefa, A., Wong, N.H., Zinzi, M., 2016. Local climate change and urban heat island mitigation techniques – the state of the art. J. Civ. Eng. Manag. 22, 1–16. doi:10.3846/13923730.2015.1111934

Alexandri, E., Jones, P., 2008. Temperature decreases in an urban canyon due to green walls and green roofs in diverse climates. Build. Environ. 43, 480–493. doi:10.1016/j.buildenv.2006.10.055

Amoly, E., Dadvand, P., Forns, J., López-Vicente, M., Basagaña, X., Julvez, J., Alvarez-Pedrerol, M., Nieuwenhuijsen, M.J., Sunyer, J., 2014. Green and blue spaces and behavioral development in Barcelona schoolchildren: The BREATHE project. Environ. Health Perspect. 122, 1351–8. doi:10.1289/ehp.1408215

Amorim, J.H., Rodrigues, V., Tavares, R., Valente, J., Borrego, C., 2013. CFD modelling of the aerodynamic effect of trees on urban air pollution dispersion. Sci. Total Environ. 461–462, 541–551. doi:10.1016/j.scitotenv.2013.05.031

Andersson, E., Barthel, S., Borgström, S., Colding, J., Elmqvist, T., Folke, C., Gren, Å., 2014. Reconnecting cities to the biosphere: Stewardship of green infrastructure and urban ecosystem services. Ambio 43, 445–453. doi:10.1007/s13280-014-0506-y

Andersson, E., Barthel, S., 2016. Memory carriers and stewardship of metropolitan landscapes. Ecol. Indic. 70, 606–614. doi:10.1016/j.ecolind.2016.02.030

Annerstedt van den Bosch, M., Mudu, P., Uscila, V., Barrdahl, M., Kulinkina, A., Staatsen, B., Swart, W., Kruize, H., Zurlyte, I., Egorov, A.I., 2016. Development of an urban green space indicator and the public health rationale. Scand. J. Public Health 44, 159–167. doi:10.1177/1403494815615444

Apollo Alliance, 2008. Green-collar jobs in America's cities: Building pathways out of poverty. http://www.cows.org/_data/documents/1165.pdf

Armson, D., Stringer, P., Ennos, A.R., 2013. The effect of street trees and amenity grass on urban surface water runoff in Manchester, UK. Urban For. Urban Green. 12, 282–286. doi:10.1016/j.ufug.2013.04.001

Aspinall, P., Mavros, P., Coyne, R., Roe, J., 2015. The urban brain: Analysing outdoor physical activity with mobile EEG. Br. J. Sports Med. 49, 272–276. doi:10.1136/bjsports-2012-091877

Atkinson, G., Mourato, S., 2015. Cost-benefit analysis and the environment. OECD Environment Working Papers No. 97. OECD Publishing, Paris. http://dx.doi.org/10.1787/5jrp6w76tstg-en

Badiu, D.L., Iojă, C.I., Pătroescu, M., Breuste, J., Artmann, M., Niță, M.R., Grădinaru, S.R., Hossu, C.A., Onose, D.A., 2016. Is urban green space per capita a valuable target to achieve cities' sustainability goals? Romania as a case study. Ecol. Indic. 70, 53–66. doi:10.1016/j.ecolind.2016.05.044

Baggett, L.P., Powers, S.P., Brumbaugh, R., Coen, L.D., DeAngelis, B., Greene, J., Hancock, B., Morlock, S., 2014. Oyster Habitat Restoration Monitoring and Assessment Handbook. Arlington, VA, USA.

Bai, L., Morton, L.C., Liu, Q., McMichael, A., Githeko, A., McMichael, A., Haines, A., …George, L., 2013. Climate change and mosquito-borne diseases in China: a review. Global. Health 9, 1-22. doi:10.1186/1744-8603-9-10

Balfour, R., Allen, J., 2014. Local action on health inequalities: Improving access to green spaces. London, UK. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/355792/Briefing8_Green_spaces_health_inequalities.pdf

Barbier, E., 2013. Valuing ecosystem services for coastal wetland protection and restoration: Progress and challenges. Resources 2, 213–230. doi:10.3390/resources2030213

Barbier, E.B., Georgiou, I.Y., Enchelmeyer, B., Reed, D.J., 2013. The Value of Wetlands in Protecting Southeast Louisiana from Hurricane Storm Surges. PLoS One 8. doi:10.1371/journal.pone.0058715

Bardosa, P., Jones, S., Stephenson, I., Menger, P., Beumer, V., Neonato, F., Maring, L., Ferber, U., Track, T., Wendler, K., 2016. Optimising value from the soft re-use of brownfield sites. Sci. Total Environ. 563–564, 769–782.

Baró, F., Chaparro, L., Gómez-Baggethun, E., Langemeyer, J., Nowak, D.J., Terradas, J., 2014. Contribution of ecosystem services to air quality and climate change mitigation policies: The case of urban forests in Barcelona, Spain. Ambio 43, 466–479. doi:10.1007/s13280-014-0507-x

Baró, F., Haase, D., Gómez-Baggethun, E., Frantzeskaki, N., 2015. Mismatches between ecosystem services supply and demand in urban areas: A quantitative assessment in five European cities. Ecol. Indic. 55, 146–158. doi:10.1016/j.ecolind.2015.03.013

Barton, H., Grant, M., 2006. A health map for the local human habitat. J. R. Soc. Promot. Health 126, 252–253. doi:10.1177/1466424006070466

Basagaña, X., Sartini, C., Barrera-Gómez, J., Dadvand, P., Cunillera, J., Ostro, B., Sunyer, J., Medina-Ramón, M., 2011. Heat waves and cause-specific mortality at all ages. Epidemiology 22, 765–772. doi:10.1097/EDE.0b013e31823031c5

Basnou, C., Pino, J., Terradas, J., 2015. Ecosystem services provided by green infrastructure in the urban environment. CAB Reviews: perspectives in agriculture, veterinary science, nutrition and natural resources. doi: 10.1079/PAVSNNR201510004

Baumgardner, D., Varela, S., Escobedo, F.J., Chacalo, A., Ochoa, C., 2012. The role of a peri-urban forest on air quality improvement in the Mexico City megalopolis. Environ. Pollut. 163, 174–83. doi:10.1016/j.envpol.2011.12.016

Bealey, W.J., McDonald, a G., Nemitz, E., Donovan, R., Dragosits, U., Duffy, T.R., Fowler, D., 2007. Estimating the reduction of urban PM10 concentrations by trees within an environmental information system for planners. J. Environ. Manage. 85, 44–58. doi:10.1016/j.jenvman.2006.07.007
Bell, F.W., 1997. The economic valuation of saltwater marsh supporting marine recreational fishing in the southeastern United States. Ecol. Econ. 21, 243–254. doi:10.1016/S0921-8009(96)00105-X
Bennett, E.M., Cramer, W., Begossi, A., Cundill, G., Díaz, S., Egoh, B.N., Geijzendorffer, I.R., Krug, C.B., Lavorel, S., Lazos, E., Lebel, L., Martín-López, B., Meyfroidt, P., Mooney, H.A., Nel, J.L., Pascual, U., Payet, K., Harguindeguy, N.P., Peterson, G.D., Prieur-Richard, A.H., Reyers, B., Roebeling, P., Seppelt, R., Solan, M., Tschakert, P., Tscharntke, T., Turner, B.L., Verburg, P.H., Viglizzo, E.F., White, P.C.L., Woodward, G., 2015. Linking biodiversity, ecosystem services, and human well-being: three challenges for designing research for sustainability. Curr. Opin. Environ. Sustain. 14, 76–85. doi:10.1016/j.cosust.2015.03.007
Berardi, U., GhaffarianHoseini, A., GhaffarianHoseini, A., 2014. State-of-the-art analysis of the environmental benefits of green roofs. Appl. Energy 115, 411–428. doi:10.1016/j.apenergy.2013.10.047
Beumer, V., Bardos, P., Menger, P., 2014. Decision support system on soft reuses. HOMBRE FP7 deliverable D 5-2.
Biddulph, M., 2011. Urban design, regeneration and the entrepreneurial city. Prog. Plann. 76, 63–103.
Biggs, R., Schluter, M., Schoon, M., 2015. Principles for Building Resilience. Cambridge University Press, Cambridge.
BOP Consulting, 2013. Green spaces: The benefits for London. London, UK. https://www.cityoflondon.gov.uk/business/economic-research-and-information/research-publications/Documents/research-2013/Green-Spaces-The-Benefits-for-London.pdf
Bottalico, F., Chirici, G., Giannetti, F., De Marco, A., Nocentini, S., Paoletti, E., Salbitano, F., Sanesi, G., Serenelli, C., Travaglini, D., 2016. Air pollution removal by green infrastructures and urban forests in the city of Florence. Agric. Agric. Sci. Procedia 8, 243–251. doi:10.1016/j.aaspro.2016.02.099
Botzat, A., Fischer, L., Kowarik, I., 2016. Unexploited opportunities in approching liveable and biodiverse cities. A review on urban biodiversity perception and valuation. Glob. Environ. Chang. 39, 220–233. doi:10.1007/s13398-014-0173-7.2
Bowler, D.E., Buyung-Ali, L., Knight, T.M., Pullin, A.S., 2010a. Urban greening to cool towns and cities: A systematic review of the empirical evidence. Landsc. Urban Plan. 97, 147–155. doi:10.1016/j.landurbplan.2010.05.006
Bowler, D.E., Buyung-Ali, L.M., Knight, T.M., Pullin, A.S., 2010b. A systematic review of evidence for the added benefits to health of exposure to natural environments. BMC Public Health 10, 456. doi:10.1186/1471-2458-10-456
Bratman, G.N., Daily, G.C., Levy, B.J., Gross, J.J., 2015a. The benefits of nature experience: Improved affect and cognition. Landsc. Urban Plan. 138, 41–50. doi:10.1016/j.landurbplan.2015.02.005
Bratman, G.N., Hamilton, J.P., Hahn, K.S., Daily, G.C., Gross, J.J., 2015b. Nature experience reduces rumination and subgenual prefrontal cortex activation. Proc. Natl. Acad. Sci. 112, 8567–8572. doi:10.1073/pnas.1510459112
Braun, V., Clarke, V., 2006. Using thematic analysis in psychology. Qual. Res. Psychol. 3, 77–101. doi:10.1191/1478088706qp063oa
Breuste, J., Haase, D., Elmqvist, T., 2013. Urban Landscapes and Ecosystem Services, in: Wratten, S., Sandhu, H., Cullen, R., Costanza, R. (Eds.), Ecosystem Services in Agricultural and Urban Landscapes. Wiley, pp. 83–104.
Brindal, M., Stringer, R., 2013. Water scarcity and urban forests: Science and public policy lessons from a decade of drought in Adelaide, Australia. Arboric. Urban For. 39, 102–108.
Brown, G., Fagerholm, N., 2014. Empirical PPGIS/PGIS mapping of ecosystem services: A review and evaluation. Ecosyst. Serv. doi:10.1016/j.ecoser.2014.10.007
Brown, G., Weber, D., de Bie, K., 2014. Assessing the value of public lands using public participation GIS (PPGIS) and social landscape metrics. Appl. Geogr. 53, 77–89. doi:10.1016/j.apgeog.2014.06.006
Brown, J.D., Damery, S.L., 2002. Managing flood risk in the UK: Towards an integration of social and technical perspectives. Trans. Inst. Br. Geogr. 27, 412–426.
Brown, R.D., Vanos, J., Kenny, N., Lenzholzer, S., 2015. Designing urban parks that ameliorate the effects of climate change. Landsc. Urban Plan. 138, 118–131. doi:10.1016/j.landurbplan.2015.02.006
Buchel, S., Frantzeskaki, N., 2015. Citizens' voice: A case study about perceived ecosystem services by urban park users in Rotterdam, the Netherlands. Ecosyst. Serv. 12, 169–177. doi:10.1016/j.ecoser.2014.11.014
Buijs, A., Elands, B., Havik, G., Ambrose-Oji, B., Gerőházi, É., van der Jagt, A., Mattijssen, T., Steen Moller, M., Vierikko, K., 2016. Innovative governance of urban green spaces – Learning from 18 innovative examples across Europe - GREEN SURGE Deliverable 6.2.
Buizer, M., Elands, B., Vierikko, K., 2015. Governing cities reflexively-The biocultural diversity concept as an alternative to ecosystem services. Environ. Sci. Policy 62, 7-13. doi:10.1016/j.envsci.2016.03.003
Burkhard, B., Kroll, F., Nedkov, S., Müller, F., 2012. Mapping ecosystem service supply, demand and budgets. Ecol. Indic. 21, 17 – 29. doi: 10.1016/j.ecolind.2011.06.019
Calaza-Martinez, P., Iglesias-Díaz, I., 2016. The risk of urban trees. Concept, context and evaluation (In Spanish). Madrid, Spain.
Calfapietra, C., Fares, S., Manes, F., Morani, A., Sgrigna, G., Loreto, F. 2013. Role of biogenic volatile organic compounds (BVOC) emitted by urban trees on ozone concentration in cities: a review. Environmental Pollution 183, 71-80.
Calfapietra, C., Niinemets, Ü., Peñuelas, J., 2015. Urban plant physiology: Adaptation-mitigation strategies under permanent stress. Trends Plant Sci. 20, 72–75. doi: 10.1016/j.tplants.2014.11.001
Camps-Calvet, M., Langemeyer, J., Calvet-Mir, L., Gómez-Baggethun, E., 2016. Ecosystem services provided by urban gardens in Barcelona, Spain: Insights for policy and planning. Environ. Sci. Policy 62, 14-23. doi:10.1016/j.envsci.2016.01.007
Cariñanos, P., Casares-Porcel, M., 2011. Urban green zones and related pollen allergy: A review. Some guidelines for designing spaces with low allergy impact. Landsc. Urban Plan. 101, 205–214. doi:10.1016/j.landurbplan.2011.03.006
Cariñanos, P., Casares-Porcel, M., Quesada-Rubio, J.-M., 2014. Estimating the allergenic potential of urban green spaces: A case-study in Granada, Spain. Landsc. Urban Plan. 123, 134–144. doi:10.1016/j.landurbplan.2013.12.009
Carrus, G., Scopelliti, M., Lafortezza, R., Colangelo, G., Ferrini, F., Salbitano, F., Agrimi, M., Portoghesi, L., Semenzato, P., Sanesi, G., 2015. Go greener, feel better? The positive effects of biodiversity on the well-being of individuals visiting urban and peri-

urban green areas. Landsc. Urban Plan. 134, 221–228. doi:10.1016/j.landurbplan.2014.10.022
Carter, J.G., 2011. Climate change adaptation in European cities. Curr. Opin. Environ. Sustain. 3, 193-198. doi:10.1016/j.cosust.2010.12.015
Chan, K.M., Guerry, A.D., Balvanera, P., Klain, S., Satterfield, T., Basurto, X., Al., E., 2012. Where are cultural and social in ecosystem services? A framework for constructive engagement. Bioscience 62, 744–756. http://dx.doi.org/ 10.1525/bio.2012.62.8.7.
Chan, K.M.A., Balvanera, P., Benessaiah, K., Chapman, M., Díaz, S., Gómez-Baggethun, E., Gould, R., Hannahs, N., Jax, K., Klain, S., Luck, G.W., Martín-López, B., Muraca, B., Norton, B., Ott, K., Pascual, U., Satterfield, T., Tadaki, M., Taggart, J., Turner, N., 2016. Why protect nature? Rethinking values and the environment. Proc. Natl. Acad. Sci. 113, 1462–1465. doi:10.1073/pnas.1525002113
Chaparo, L., Terrasdas, J., 2009. Ecological services of urban forest in Barcelona. CREAF, Spain. doi:10.13140/RG.2.1.4013.9604
Chapin, F.S., Carpenter, S.R., Kofinas, G.P., Folke, C., Abel, N., Clark, W.C., Olsson, P., Smith, D.M., Walker, B., Young, O.R., Berkes, F., Biggs, R., Grove, J.M., Naylor, R.L., Pinkerton, E., Steffen, W., Swanson, F.J., 2010. Ecosystem stewardship: sustainability strategies for a rapidly changing planet. Trends Ecol. Evol. 25, 241–249. doi: 10.1016/j.tree.2009.10.008
Checker, M., 2011. Wiped out by the “Greenwave”: Environmental gentrification and the paradoxical politics of urban sustainability. City Soc. 23, 210–229. doi:10.1111/j.1548-744X.2011.01063.x
Chen, S.S., Luoh, M.C., 2010. Are mathematics and science test scores good indicators of labor-force quality? Soc. Indic. Res. 96, 133–143. doi:10.1007/s11205-009-9470-5
Chen, D., Wang, X., Thatcher, M., Barnett, G., Kachenko, A., Prince, R., 2014. Urban vegetation for reducing heat related mortality. Environ. Pollut. 192, 275–284. doi:10.1016/j.envpol.2014.05.002
City of Copenhagen, 2014. The City of Copenhagen cloudburst management plan 2012. City of Copenhagen, Denmark.
City of Helsinki, 2014. City Planning Department’s report on sea areas of Helsinki for proposal for Helsinki City Plan http://www.hel.fi/hel2/ksv/julkaisut/yos 2014-15.pdf
City of New York., 2014. A Stronger, More Resilient New York. New York, New York, USA. http://s-media.nyc.gov/agencies/sirr/SIRR_singles_Lo_res.pdf
Claus, K., Rousseau, S., 2012. Public versus private incentives to invest in green roofs: A cost benefit analysis for Flanders. Urban For. Urban Green. 11, 417–425. doi:10.1016/j.ufug.2012.07.003
Cohen-Shacham, E., Walters, G., Janzen, C., Maginnis, S., 2016. Nature-based Solutions to address global societal challenges. IUCN, Gland, Switzerland. doi:10.2305/IUCN.CH.2016.13.en
Cohen, M., Baudoin, R., Palibrk, M., Persyn, N., Rhein, C., 2012. Urban biodiversity and social inequalities in built-up cities: New evidences, next questions. The example of Paris, France. Landsc. Urban Plan. 106, 277–287. doi:10.1016/j.landurbplan.2012.03.007
Colding, J., Barthel, S., 2013. The potential of “Urban Green Commons” in the resilience building of cities. Ecol. Econ. 86, 156–166. doi:10.1016/j.ecolecon.2012.10.016
Collier, M.J., Nedović-Budić, Z., Aerts, J., Connop, S., Foley, D., Foley, K., Newport, D., McQuaid, S., Slaev, A., Verburg, P., 2013. Transitioning to resilience and sustainability in urban communities. Cities 32, S21–S28. doi:10.1016/j.cities.2013.03.010
Collins, A., Coughlin, D., Miller, J., Kirk, S., 2015. The production of quick scoping reviews and rapid evidence assessments: A how to guide. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/560521/Production_of_quick_scoping_reviews_and_rapid_evidence_assessments.pdf
Comim, F., Qizilbash, M., Alkire, S. (Eds.), 2008. The Capability Approach. Concepts, Measures and Applications. Cambridge University Press, Cambridge.
Comstock, N., Dickinson, L.M., Marshall, J.A., Soobader, M.-J.J., Turbin, M.S., Buchenau, M., Litt, J.S., Miriam Dickinson, L., 2010. Neighborhood attachment and its correlates: Exploring neighborhood conditions, collective efficacy and gardening. J. Environ. Psychol. 30, 435–442. doi:10.1016/j.jenvp.2010.05.001
Connolly, J.J.T., Svendsen, E.S., Fisher, D.R., Campbell, L.K., 2014. Networked governance and the management of ecosystem services: The case of urban environmental stewardship in New York City. Ecosyst. Serv. 10, 187–194. doi: 10.1016/j.ecoser.2014.08.005
Couch, C., Fraser, C., Percy, S. (Eds), 2008. Urban Regeneration in Europe. Blackwell, Oxford.
Cozens, P., Love, T., 2015. A review and current status of crime prevention through environmental design (CPTED). J. Plan. Lit. 30, 393–412. doi:10.1177/0885412215595440
Crowe, P.R., Foley, K., Collier, M.J., 2016. Operationalizing urban resilience through a framework for adaptive co-management and design: Five experiments in urban planning practice and policy. Environ. Sci. Policy 62, 112–119. doi:10.1016/j.envsci.2016.04.007
Cvejić, R., Eler, K., Pintar, M., Železnikar, Š., Haase, D., Kabisch, N., Strohbach, M., 2015. A typology of urban green spaces, eco-system provisioning services and demands. EU FP7 GREEN SURGE Deliverable, Report D3.1.
Dadvand, P., de Nazelle, A., Triguero-Mas, M., Schembari, A., Cirach, M., Amoly, E., Figueras, F., Basagaña, X., Ostro, B., Nieuwenhuijsen, M., 2012. Surrounding greenness and exposure to air pollution during pregnancy: An analysis of personal monitoring data. Environ. Health Perspect. 120, 1286–1290. doi:10.1289/ehp.1104609
Daily, G.C., Polasky, S., Goldstein, J., Kareiva, P.M., Mooney, H.A., Pejchar, L., Ricketts, T.H., Salzman, J., Shallenberger, R., 2009. Ecosystem services in decision making: Time to deliver. Front. Ecol. Environ. 7, 21–28. doi:10.1890/080025
Davies, Z.G., Edmondson, J.L., Heinemeyer, A., Leake, J.R., Gaston, K.J., 2011. Mapping an urban ecosystem service: Quantifying above-ground carbon storage at a city-wide scale. J. Appl. Ecol. 48, 1125–1134. doi:10.1111/j.1365-2664.2011.02021.x
Davies, C., Hansen, R., Rall, E., Pauleit, S., Lafortezza, R., Bellis, Y. De, Santos, A., Tosics, I., 2015. Green infrastructure planning and implementation. EU FP7 GREEN SURGE Deliverable, Report 5.1. doi:10.13140/RG.2.1.1723.0888
Davis, A., Hunt, W., Traver, R., Clar, M., 2009. Bioretention technology: Overview of current practice and future needs. J. Environ.

Eng. 135, 109–117. doi:10.1061/(ASCE)0733-9372
de Groot, R.S.S., Alkemade, R., Braat, L., Hein, L., Willemen, L., 2010. Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecol. Complex. 7, 260–272. doi:10.1016/j.ecocom.2009.10.006
de Moel, H., Jongman, B., Kreibich, H., Merz, B., Penning-Rowsell, E., Ward, P.J., 2015. Flood risk assessments at different spatial scales. Mitig. Adapt. Strateg. Glob. Chang. 20, 865–890. doi:10.1007/s11027-015-9654-z
de Vries, S., van Dillen, S.M.E., Groenewegen, P.P., Spreeuwenberg, P., 2013. Streetscape greenery and health: Stress, social cohesion and physical activity as mediators. Soc. Sci. Med. 94, 26–33. doi:10.1016/j.socscimed.2013.06.030
Deakin, M., Allwinkle, S., 2007. Urban regeneration and sustainable communities: The role of networks, innovation, and creativity in building successful partnerships. J. Urban Technol. 14, 77-91. doi:10.1080/10630730701260118
Demuzere, M., Orru, K., Heidrich, O., Olazabal, E., Geneletti, D., Orru, H., Bhave, A.G., Mittal, N., Feliu, E., Faehnle, M., 2014. Mitigating and adapting to climate change: Multi-functional and multi-scale assessment of green urban infrastructure. J. Environ. Manage. 146, 107–115. doi:10.1016/j.jenvman.2014.07.025
Deng, Y., Cardin, M.-A., Babovic, V., Santhanakrishnan, D., Schmitter, P., Meshgi, A., 2013. Valuing flexibilities in the design of urban water management systems. Water Res. 47, 7162–7174. doi:10.1016/j.watres.2013.09.064
Dennis, M., James, P., 2016. User participation in urban green commons: Exploring the links between access, voluntarism, biodiversity and well being. Urban For. Urban Green. 15, 22–31. doi:10.1016/j.ufug.2015.11.009
Derkzen, M.L., van Teeffelen, A.J.A., Verburg, P.H., 2015. Quantifying urban ecosystem services based on high-resolution data of urban green space: An assessment for Rotterdam, the Netherlands. J. Appl. Ecol. 52, 1020–1032. doi:10.1111/1365-2664.12469
Derkzen, M.L., van Teeffelen, A.J.A., Verburg, P.H., 2017. Green infrastructure for urban climate adaptation: How do residents' views on climate impacts and green infrastructure shape adaptation preferences? Landsc. Urban Plan. 157, 106–130. doi:10.1016/j.landurbplan.2016.05.027
Dhakal, K.P., Chevalier, L.R., 2016. Urban stormwater governance: The need for a paradigm shift. Environ. Manage. 57, 1112–24. doi:10.1007/s00267-016-0667-5
Dicks, L. V., Walsh, J.C., Sutherland, W.J., 2014. Organising evidence for environmental management decisions: A "4S" hierarchy. Trends Ecol. Evol. 29, 607–613. doi:10.1016/j.tree.2014.09.004
Dooling, S., 2009. Ecological gentrification: A research agenda exploring justice in the city. Int. J. Urban Reg. Res. 33, 621–639. doi:10.1111/j.1468-2427.2009.00860.x
Dramstad, W.E., Olsson, J.D., Forman, R.T., 1996. Landscape ecology principles in landscape architecture and land-use planning. Island Press. Washington, D.C.
Dravigne, A., Waliczek, T.M., Lineberger, R.D., Zajicek, J.M., 2008. The effect of live plants and window views of green spaces on employee perceptions of job satisfaction. HortScience 43, 183–187.
Dunn, W.N., 2004. Public policy analysis: An Introduction. Pearson Publishing, New York.
Eftec, 2013. Green Infrastructure's contribution to economic growth: a review. A Final Report for DEFRA and Natural England, London.
EKLIPSE, 2016. EKLIPSE Document of work: Request NBS framework (internal unpublished document).
Elands, B.H.M., Wiersum, K.F., Buijs, A.E., Vierikko, K., 2015. Policy interpretations and manifestation of biocultural diversity in urbanized Europe: Conservation of lived biodiversity. Biodivers. Conserv. 24, 3347–3366. doi:10.1007/s10531-015-0985-6
Elliott, J., Lee, S.W., Tollefson, N., 2001. A reliability and validity study of the dynamic indicators of basic early literacy skills-modified. School Psych. Rev. 30.
Elmqvist, T., Setala, H., Handel, S.N., van der Ploeg, S., Aronson, J., Blignaut, J.N., Gomez-Baggethun, E., Nowak, D.J., Kronenberg, J., de Groot, R., 2015. Benefits of restoring ecosystem services in urban areas. Curr. Opin. Environ. Sustain. 14, 101–108. doi:10.1016/j.cosust.2015.05.001
Ernstson, H., Sörlin, S., Elmqvist, T., 2009. Social movements and ecosystem services — the role of social network structure in protecting and managing urban green areas in Stockholm. Ecol. Soc. 13, 39–65. doi:10.1002/pad
Ernstson, H., 2013. The social production of ecosystem services: A framework for studying environmental justice and ecological complexity in urbanized landscapes. Landsc. Urban Plan. 109, 7–17. doi:10.1016/j.landurbplan.2012.10.005
Escobedo, F.J., Kroeger, T., Wagner, J.E., 2011. Urban forests and pollution mitigation: Analyzing ecosystem services and disservices. Environ. Pollut. 159, 2078–2087. doi:10.1016/j.envpol.2011.01.010
Escobedo, F.J., Nowak, D.J., 2009. Spatial heterogeneity and air pollution removal by an urban forest. Landsc. Urban Plan. 90, 102–110. doi:10.1016/j.landurbplan.2008.10.021
European Commission, 2013. Mapping and assessment of ecosystems and their services. An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020. Technical Report - 2013 – 067. Publications Office of the European Union, Luxembourg.
European Commission, 2014. Mapping and Assessment of Ecosystems and their Services Indicators for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020. Technical Report - 2014 – 080. Publications Office of the European Union, Luxembourg.
European Commission, 2015. Towards an EU research and innovation policy agenda for nature-based solutions & re-naturing cities. Final report of the Horizon 2020 expert group on "Nature-based solutions and re-naturing cities." Brussels.
European Commission, 2016. Policy topics: Nature-based Solutions. https://ec.europa.eu/research/environment/index.cfm?pg=nbs.
Fagherazzi, S., 2014. Coastal processes: Storm-proofing with marshes. Nat. Geosci. 7, 701–702. doi:10.1038/ngeo2262
Falxa-Raymond, N., Svendsen, E., Campbell, L.K., 2013. From job training to green jobs: A case study of a young adult employment program centered on environmental restoration in New York City, USA. Urban For. Urban Green. 12, 287–295.

doi:10.1016/j.ufug.2013.04.003
Farr, D. (Ed.), 2011. Sustainable Urbanism: Urban Design with Nature. Wiley, UK.
Felson, M., Poulsen, E., 2003. Simple indicators of crime by time of day. Int. J. Forecast. doi:10.1016/S0169-2070(03)00093-1
Fernandez, F.J., Alvarez-Velazquez, L.J., Garcia-Chan, N., Martinez, A., Velazquez-Mendez, M.E., 2015. Optimal location of green zones in metropolitan areas to control the urban heat island. J. Comput. Appl. Math. 289, 412–425. doi:10.1016/j.cam.2014.10.023
Feyen, L., Gorelick, S., 2004. Reliable groundwater management in hydroecologically sensitive areas. Water Resour. Res. 40, 1–14. doi:10.1029/2003WR003003
Filibeck, G., Petrella, P., Cornelini, P., 2016. All ecosystems look messy, but some more so than others: A case-study on the management and acceptance of Mediterranean urban grasslands. Urban For. Urban Green. 15, 32–39. doi:10.1016/j.ufug.2015.11.005
Fioretti, R., Palla, A., Lanza, L.G., Principi, P., 2010. Green roof energy and water related performance in the Mediterranean climate. Build. Environ. 45, 1890–1904.
Fisher, B., Turner, R.K., Morling, P., 2009. Defining and classifying ecosystem services for decision making. Ecol. Econ. 68, 643 – 653. doi:10.1016/j.ecolecon.2008.09.014
Flint, C.G., Kunze, I., Muhar, A., Yoshida, Y., Penker, M., 2013. Exploring empirical typologies of human–nature relationships and linkages to the ecosystem services concept. Landsc. Urban Plan. 120, 208–217. doi:10.1016/j.landurbplan.2013.09.002
Forestry Commission 2005. Bold Colliery Community Woodland: District valuer's report on property values. Forestry Commission, North West England Conservancy, Penrith.
Fors, H., Molin, J.F., Murphy, M.A., Bosch, C.K. van den, 2015. User participation in urban green spaces–for the people or the parks? Urban For. Urban Green. 14, 722–734. doi:10.1016/j.ufug.2015.05.007
Frantzeskaki, N., Kabisch, N., 2016. Setting a knowledge co-production operating space for urban environmental governance: Lessons from Rotterdam, Netherlands and Berlin, Germany. Environ. Sci. Policy 62, 1–9. doi:10.1016/j.envsci.2016.01.010
Frantzeskaki, N., Tilie, N., 2014. The dynamics of urban ecosystem governance in Rotterdam, the Netherlands. Ambio 43, 542–555. doi:10.1007/s13280-014-0512-0
Fraser, N., 2009. Scales of Justice: Reimagining Political Space in a Globalizing World. Columbia University Press.
Gabrielsen, P., Bosch, P. 2003. Environmental indicators: Typology and use in reporting. European Environment Agency, Denmark.
Gascon, M., Triguero-Mas, M., Martínez, D., Dadvand, P., Rojas-Rueda, D., Plasència, A., 2016. Residential green spaces and mortality: A systematic review. Environ. Int. 86, 60–67.
Gedan, K.B., Kirwan, M.L., Wolanski, E., Barbier, E.B., Silliman, B.R., 2011. The present and future role of coastal wetland vegetation in protecting shorelines: Answering recent challenges to the paradigm. Clim. Change 106, 7–29. doi:10.1007/s10584-010-0003-7
Gehrels, H., Meulen, S. Van Der, Schasfoort, F., Goossens, M., Jacobs, C., Jong, M. De, Kok, S., Massop, H., Osté, L., Pérez-soba, M., Rovers, V., Smit, A., Verweij, P., Vries, B. De, Weijers, E., 2016. Designing green and blue infrastructure to support healthy urban living. Technical Report by the TO2 Federatie. http://publications.deltares.nl/WeL1839.pdf
Gensler and the Urban Land Institute, 2011. Open Space: An asset without a champion? Report for the Urban Investment Network.
Gerstenberg, T., Hofmann, M., 2016. Perception and preference of trees: A psychological contribution to tree species selection in urban areas. Urban For. Urban Green. 15, 103–111. doi:10.1016/j.ufug.2015.12.004
Getter, K.L., Rowe, D.B., Andresen, J.A., 2007. Quantifying the effect of slope on extensive green roof stormwater retention. Ecol. Eng. 31, 225–231. doi:10.1016/j.ecoleng.2007.06.004
Ghervase, L., Ioja, C., Carstea, E.M., Savastru, D., 2012. Human Daily Activities Reflected by the Ecological State of Natural Water Resources. Environ. Eng. Manag. J. 11, 567–571.
Giannico, V., Lafortezza, R., John, R., Sanesi, G., Pesola, L., Chen, J., 2016. Estimating stand volume and above-ground biomass of urban forests using LiDAR. Remote Sens. 8, 339. doi:10.3390/rs8040339
Gifford, R., 2014. Environmental psychology matters. Annu. Rev. Psychol. 65, 541–79. doi:10.1146/annurev-psych-010213-115048
Goddard, M.A., Dougill, A.J., Benton, T.G., 2010. Scaling up from gardens: biodiversity conservation in urban environments. Trends Ecol. Evol. 25, 90–98.
Gómez-Baggethun, E., Barton, D.N., 2013. Classifying and valuing ecosystem services for urban planning. Ecol. Econ. 86, 235–245. doi:10.1016/j.ecolecon.2012.08.019
Grabowski, J.H., Brumbaugh, R.D., Conrad, R.F., Keeler, A.G., Opaluch, J.J., Peterson, C.H., Piehler, M.F., Powers, S.P., Smyth, A.R., 2012. Economic valuation of ecosystem services provided by oyster reefs. Am. Institure Biol. Sci. 62, 900–909. doi:10.1525/bio.2012.62.10.10
Gray, S.A., Gray, S., de Kok, J.L., Helfgott, A.E.R., O'Dwyer, B., Jordan, R., Nyaki, A., 2015. Using fuzzy cognitive mapping as a participatory approach to analyze change, preferred states, and perceived resilience of social-ecological systems. Ecol. Soc. 20.
Grimm, N.B., Faeth, S.H., Golubiewski, E.N., Redman, C.L., Wu, J., Bai, X., Briggs, J.M., 2008. Global change and the ecology of cities. Science 319, 756–760.
Grote, R., Samson, R., Alonso, R., Amorim, J.H,, Cariñanos, P., Churkina, G., Fares, S., Le Thiec, D., Lo Niinemets, Ü., Mikkelsen, T.N., Paoletti, E., Tiwary, A., Calfapietra, C. 2017. Functional traits of urban trees in relation to their air pollution mitigation potential: A holistic discussion. Frontiers in Ecology and the Environment, in press.
Guerry, A.D., Polasky, S., Lubchenco, J., Chaplin-Kramer, R., Daily, G.C., Griffin, R., Ruckelshaus, M., Bateman, I.J., Duraiappah, A., Elmqvist, T., Feldman, M.W., Folke, C., Hoekstra, J., Kareiva, P.M., Keeler, B.L., Li, S., McKenzie, E., Ouyang, Z., Reyers, B., Ricketts, T.H., Rockström, J., Tallis, H., Vira, B., 2015. Natural capital and ecosystem services informing decisions: From promise to practice. Proc. Natl. Acad. Science. 112, 201503751. doi:10.1073/pnas.1503751112
Haase, D., 2015. Reflections about blue ecosystem services in cities. Sustain. Water Qual. Ecol. 5, 77–83.

doi:10.1016/j.swaqe.2015.02.003
Haase, D., Schwarz, N., Strohbach, M., Kroll, F., Seppelt, R., 2012. Synergies, trade-offs, and losses of ecosystem services in urban regions: An integrated multiscale framework applied to the Leipzig-Halle region, Germany. Ecol. Soc. 17, 2012. doi:10.5751/ES-04853-170322
Haase, D., Larondelle, N., Andersson, E., Artmann, M., Borgström, S., Breuste, J., Gomez-Baggethun, E., Gren, Å., Hamstead, Z., Hansen, R., Kabisch, N., Kremer, P., Langemeyer, J., Rall, E.L., McPhearson, T., Pauleit, S., Qureshi, S., Schwarz, N., Voigt, A., Wurster, D., Elmqvist, T., 2014. A Quantitative Review of Urban Ecosystem Service Assessments: Concepts, Models, and Implementation. Ambio 43, 413–433. doi:10.1007/s13280-014-0504-0
Hansen, R., Frantzeskaki, N., McPhearson, T., Rall, E., Kabisch, N., Kaczorowska, A., Kain, J.-H., Artmann, M., Pauleit, S., 2015. The uptake of the ecosystem services concept in planning discourses of European and American cities. Ecosyst. Serv. 12, 228–246. doi:10.1016/j.ecoser.2014.11.013
Hansen, R., Rolf, W., Santos, A., Luz, A.C., Száraz, L., Tosics, I., Vierikko, K., Rall, E., Davies, C., Pauleit, S., 2016. Advanced Urban Green Infrastructure Planning. doi:10.13140/RG.2.1.4813.2243
Harrison, P.A., Berry, P.M., Simpson, G., Haslett, J.R., Blicharska, M., Bucur, M., Dunford, R., .. and Turkelboom, F., 2014. Linkages between biodiversity attributes and ecosystem services: A systematic review. Ecosystem Services 9, 191-203.
Hartig, T., Mitchell, R., de Vries, S., Frumkin, H., 2014. Nature and health. Annu. Rev. Public Health 35, 207–28. doi:10.1146/annurev-publhealth-032013-182443
Heft, H., 2012. Foundations of an Ecological Approach to Psychology, in: Clayton, S.D. (Ed.), The Oxford Handbook of Environmental and Conservation Psychology. Oxford University Press, Oxford, UK, pp. 11–40.
Hein, L., van Koppen, K., de Groot, R., van Ierland, E.C.., 2006. Spatial scales, stakeholders and the valuation of ecosystem services.Ecological Economics 57, 209–28. doi:10.1016/j.ecolecon.2005.04.005.
Hemphill, L., Berry, J., McGreal, S., 2004. An indicator-based approach to measuring sustainable urban regeneration performance: Part 1, conceptual foundations and methodological framework. Urban Stud. 41. doi:10.1080/0042098042000194089
Honold, J., Beyer, R., Lakes, T., van der Meer, E., 2012. Multiple environmental burdens and neighborhood-related health of city residents. J. Environ. Psychol. 32, 305–317. doi:10.1016/j.jenvp.2012.05.002
Honold, J., Lakes, T., Beyer, R., van der Meer, E., 2016. Restoration in urban spaces: Nature views from home, greenways, and public parks. Environ. Behav. 48, 796–825. doi:10.1177/0013916514568556
Howe, C., Suich, H., Vira, B., Mace, G.M., 2014. Creating win-wins from trade-offs? Ecosystem services for human well-being: A meta-analysis of ecosystem service trade-offs and synergies in the real world. Glob. Environ. Chang. 28, 263–275. doi:10.1016/j.gloenvcha.2014.07.005
Hughey, S.M., Walsemann, K.M., Child, S., Powers, A., Reed, J.A., Kaczynski, A.T., 2016. Using an environmental justice approach to examine the relationships between park availability and quality indicators, neighborhood disadvantage, and racial/ethnic composition. Landsc. Urban Plan. 148, 159–169. doi:10.1016/j.landurbplan.2015.12.016
Huntsinger, L., Oviedo, J.L., 2014. Ecosystem services are social – ecological services in a traditional pastoral system : The case of California ' s mediterranean rangelands. Ecol. Soc. 19, 8. doi:10.5751/es-06143-190108
Iacob, O., Rowan, J.S., Brown, I., Ellis, C., 2014. Evaluating wider benefits of natural flood management strategies: An ecosystem-based adaptation perspective. Hydrol. Res. 45, 774–787. doi:10.2166/nh.2014.184
Ibes, D.C., 2015. A multi-dimensional classification and equity analysis of an urban park system: A novel methodology and case study application. Landsc. Urban Plan. 137, 122–137. doi:10.1016/j.landurbplan.2014.12.014
Iojă, C.I., Grădinaru, S.R., Onose, D.A., Vânău, G.O., Tudor, A.C., 2014. The potential of school green areas to improve urban green connectivity and multifunctionality. Urban For. Urban Green. 13, 704–713. doi:10.1016/j.ufug.2014.07.002
IPCC, 2014. Climate Change 2014: Impacts, adaptation, and vulnerability. Part B: Regional aspects. Contribution of working group II to the fifth assessment report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandr]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
Jiang, P., Xu, B., Dong, W., Chen, Y., Xue, B., 2016. Assessing the environmental sustainability with a co-benefits approach: a study of industrial sector in Baoshan District in Shanghai. J. Clean. Prod. 114, 114–123. doi:10.1016/j.jclepro.2015.07.159
Jin, S., Guo, J., Wheeler, S., Kan, L., Che, S., 2014. Evaluation of impacts of trees on PM2.5 dispersion in urban streets. Atmos. Environ. 99, 277–287. doi:10.1016/j.atmosenv.2014.10.002
Joshi, S. V., Ghosh, S., 2014. On the air cleansing efficiency of an extended green wall: A CFD analysis of mechanistic details of transport processes. J. Theor. Biol. 361, 101–110. doi:10.1016/j.jtbi.2014.07.018
Kabisch, N., 2015. Ecosystem service implementation and governance challenges in urban green space planning — The case of Berlin, Germany. Land Use Policy 42, 557–567. doi:10.1016/j.landusepol.2014.09.005
Kabisch, N., Qureshi, S., Haase, D., 2015. Human–environment interactions in urban green spaces — A systematic review of contemporary issues and prospects for future research. Environ. Impact Assess. Rev. 50, 25–34. doi:10.1016/j.eiar.2014.08.007
Kabisch, N., Frantzeskaki, N., Pauleit, S., Naumann, S., Davis, M., Artmann, M., Haase, D., Knapp, S., Korn, H., Stadler, J., Zaunberger, K., Bonn, A., 2016. Nature-based solutions to climate change mitigation and adaptation in urban areas: Perspectives on indicators, knowledge gaps, barriers, and opportunities for action. Ecol. Soc. 21, art39. doi:10.5751/ES-08373-210239
Kabisch, N., Haase, D., 2014. Green justice or just green? Provision of urban green spaces in Berlin, Germany. Landsc. Urban Plan. 122, 129–139. doi:10.1016/j.landurbplan.2013.11.016
Kati, V., Jari, N., 2016. Bottom-up thinking—Identifying socio-cultural values of ecosystem services in local blue–green infrastructure planning in Helsinki, Finland. Land Use Policy 50, 537–547. doi:10.1016/j.landusepol.2015.09.031
Kaźmierczak, A., 2012. Heat and social vulnerability in Greater Manchester: A risk-response case study. EcoCities Project. Manchester, UK.
Kaźmierczak, A., 2013. The contribution of local parks to neighbourhood social ties. Landsc. Urban Plan. 109, 31–44.

doi:10.1016/j.landurbplan.2012.05.007
Kaźmierczak, A., Carter, J., 2014. Adaptation to climate change using green and blue infrastructure. A database of case studies. Report for the Interreg IVC Green and blue space adaptation for urban areas and eco towns (GRaBS) project. Manchester, UK.
Keeley, M., Koburger, A., Dolowitz, D.P., Medearis, D., Nickel, D., Shuster, W., 2013. Perspectives on the use of green infrastructure for stormwater management in Cleveland and Milwaukee. Environ. Manage. 51, 1093–1108. doi:10.1007/s00267-013-0032-x
Kendrick, D., Mulvaney, C., Burton, P., Watson, M., 2005. Relationships between child, family and neighbourhood characteristics and childhood injury: A cohort study. Soc. Sci. Med. 61, 1905–1915. doi:10.1016/j.socscimed.2005.04.003
Keniger, L.E., Gaston, K.J., Irvine, K.N., Fuller, R.A., 2013. What are the benefits of interacting with nature? Int. J. Environ. Res. Public Health 10, 913–35. doi:10.3390/ijerph10030913
Kenter, J., 2016. Integrating deliberative monetary valuation, systems modelling and participatory mapping to assess shared values of ecosystem services. Ecosytem Serv. In press.
Kenter, J.O., O'Brien, L., Hockley, N., Ravenscroft, N., Fazey, I., Irvine, K.N., Reed, M.S., Christie, M., Brady, E., Bryce, R., Church, A., Cooper, N., Davies, A., Evely, A., Everard, M., Fish, R., Fisher, J.A., Jobstvogt, N., Molloy, C., Orchard-Webb, J., Ranger, S., Ryan, M., Watson, V., Williams, S., 2015. What are shared and social values of ecosystems? Ecol. Econ. 111, 86–99. doi:10.1016/j.ecolecon.2015.01.006
Kim, J.H., Lee, C., Olvara, N.E., Ellis, C.D., 2014. The role of landscape spatial patterns on obesity in Hispanic children residing in inner-city neighborhoods. J. Phys. Act. Heal. 11, 1449–1457. doi:10.1123/jpah.2012-0503
Klasen, S., 2008. Economic growth and poverty reduction: Measurement issues using income and non-income indicators. World Dev. 36, 420–445. doi:10.1016/j.worlddev.2007.03.008
Krasny, M.E., Lundholm, C., Kobori, H., 2013. Urban landscapes as learning arenas for biodiversity and ecosystem services management. Springer Netherlands, pp. 629–664. doi:10.1007/978-94-007-7088-1_30
Krasny, M.E., Russ, A., Tidball, K.G., Elmqvist, T., 2014. Civic ecology practices: Participatory approaches to generating and measuring ecosystem services in cities. Ecosyst. Serv. 7, 177–186. doi:10.1016/j.ecoser.2013.11.002
Kretsch, C., Kelemen, E., 2015. Ecosystem services and social justice. OpenNESS Synth. Pap. 1–7.
Kuo, M., 2015. How might contact with nature promote human health? Promising mechanisms and a possible central pathway. Front. Psychol. 6, 1093. doi:10.3389/fpsyg.2015.01093
Kyttä, M., & Kahila, M., 2011. SoftGIS methodology. GIM International, 25(3).
La Rosa, D., Spyra, M., Inostroza, L., 2016. Indicators of cultural ecosystem services for urban planning: A review. Ecol. Indic. 61, 74–89. doi:10.1016/j.ecolind.2015.04.028
Laatikainen, T., Tenkanen, H., Kyttä, M., Toivonen, T., 2015. Comparing conventional and PPGIS approaches in measuring equality of access to urban aquatic environments. Landsc. Urban Plan. 144, 22–33. doi:10.1016/j.landurbplan.2015.08.004
Landscape Institute, 2009. Green infrastructure: Connected and multifunctional landscapes. Landsc. Inst. 30. www.landscapeinstitute.org
Langemeyer, J., Gómez-Baggethun, E., Haase, D., Scheuer, S., Elmqvist, T., 2016. Bridging the gap between ecosystem service assessments and land-use planning through Multi-Criteria Decision Analysis (MCDA). Environ. Sci. Policy 62, 45–56.
Laprise, M., Lufkin, S., Rey, E., 2015. An indicator system for the assessment of sustainability integrated into the project dynamics of regeneration of disused urban areas. Build. Environ. 86. doi:10.1016/j.buildenv.2014.12.002
Lawrence, E.J., Shaw, P., Baker, D., Baron-Cohen, S., David, A.S., 2004. Measuring empathy: reliability and validity of the Empathy Quotient. Psychol. Med. 34, 911–9.
Lee, A.C.K., Maheswaran, R., 2011. The health benefits of urban green spaces: A review of the evidence. J. Public Health (Bangkok). 33, 212–222. doi:10.1093/pubmed/fdq068
Lehmann, I., Mathey, J., Rößler, S., Bräuer, A., Goldberg, V., 2014. Urban vegetation structure types as a methodological approach for identifying ecosystem services – Application to the analysis of micro-climatic effects. Ecol. Indic. 42, 58–72. doi:10.1016/j.ecolind.2014.02.036
Leikkilä, J., Faehnle, M., Galanakis, M., 2013. Promoting interculturalism by planning of urban nature. Urban For. Urban Green. 12, 183–190. doi:10.1016/j.ufug.2013.02.002
Leonardsen, J.A., 2013. Cloudburst adaptation a cost-benefit analysis. Produced by Ramboll for The Municipality of Copenhagen.
Li, Y., Babcock, R.W., 2014. Green roofs against pollution and climate change: A review. Agron. Sustain. Dev. 34, 695–705. doi:10.1007/s13593-014-0230-9
Litvak, E., Pataki, D.E., 2016. Evapotranspiration of urban lawns in a semi-arid environment: An in situ evaluation of microclimatic conditions and watering recommendations. J. Arid Environ. 134, 87–96. doi:10.1016/j.jaridenv.2016.06.016
Liu, W., Chen, W., Peng, C., 2014. Assessing the effectiveness of green infrastructures on urban flooding reduction: A community scale study. Ecol. Modell. 291, 6–14.
Lõhmus, M., Balbus, J., 2015. Making green infrastructure healthier infrastructure. Infect. Ecol. Epidemiol. 5, 30082. doi:10.3402/iee.v5.30082
Luttik, J., 2000. The value of trees, water and open spaces as reflected by house prices in the Netherlands. Landscape and Urban Planning. 48 (3-4), 161-167.
Luyet, V., Schlaepfer, R., Parlange, M.B., Buttler, A., 2012. A framework to implement stakeholder participation in environmental projects. J. Environ. Manage. 111, 213–219. doi:10.1016/j.jenvman.2012.06.026
Lynch, S. V., Wood, R.A., Boushey, H., Bacharier, L.B., Bloomberg, G.R., Kattan, M., O'Connor, G.T., Sandel, M.T., Calatroni, A., Matsui, E., Johnson, C.C., Lynn, H., Visness, C.M., Jaffee, K.F., Gergen, P.J., Gold, D.R., Wright, R.J., Fujimura, K., Rauch, M., Busse, W.W., Gern, J.E., 2014. Effects of early-life exposure to allergens and bacteria on recurrent wheeze and atopy in urban children. J. Allergy Clin. Immunol. 134, 593–601.e12. doi:10.1016/j.jaci.2014.04.018
Maas, J., Verheij, R. a, Groenewegen, P.P., de Vries, S., Spreeuwenberg, P., 2006. Green space, urbanity, and health: how strong is

the relation? J. Epidemiol. Community Health 60, 587–92. doi:10.1136/jech.2005.043125
Maas, J., Verheij, R.A., de Vries, S., Spreeuwenberg, P., Schellevis, F.G., Groenewegen, P.P., 2009. Morbidity is related to a green living environment. J. Epidemiol. Community Heal. 63, 967–973. doi:10.1136/jech.2008.079038
Madureira, H., Andresen, T., Monteiro, A., 2011. Green structure and planning evolution in Porto. Urban For. Urban Green. 10, 141–149. doi:10.1016/j.ufug.2010.12.004
Madureira, H., Nunes, F., Oliveira, J. V, Cormier, L., Madureira, T., 2015. Urban residents' beliefs concerning green space benefits in four cities in France and Portugal. Urban For. Urban Green. 14, 56–64. doi:10.1016/j.ufug.2014.11.008
Manes, F., Marando, F., Capotorti, G., Blasi, C., Salvatori, E., Fusaro, L., Ciancarella, L., Mircea, M., Marchetti, M., Chirici, G., Munafò, M., 2016. Regulating ecosystem services of forests in ten Italian metropolitan cities: Air quality improvement by PM10 and O3 removal. Ecol. Indic. 67, 425–440. doi:10.1016/j.ecolind.2016.03.009
Manso, M., Castro-Gomes, J., 2015. Green wall systems: A review of their characteristics. Renew. Sustain. Energy Rev. 41, 863–871. doi:10.1016/j.rser.2014.07.203
Manzo, L.C., Devine-Wright, P., 2014. Place Attachment: Advances in Theory, Methods and Applications. Routledge, Oxon.
Martos, A., Pacheco-Torres, R., Ordóñez, J., Jadraque-Gago, E., 2016. Towards successful environmental performance of sustainable cities: Intervening sectors. A review. Renew. Sustain. Energy Rev. 57, 479–495. doi:10.1016/j.rser.2015.12.095
Mathey, J., Rößler, S., Banse, J., Lehmann, I., Bräuer, A., 2015. Brownfields as an element of green infrastructure for implementing ecosystem services into urban areas. J. Urban Plan. Dev. 141, A4015001. doi:10.1061/(ASCE)UP.1943-5444.0000275
Mazza, L., Bennett, G., De Nocker, L., Gantioler, S., Losarcos, L., Margerison, C., Kaphengst, T., McConville, A., Rayment, M., ten Brink, P., Tucker, G., van Diggelen, R., 2011. Green infrastructure implementation and efficiency. Final Rep. Eur. Comm. DG Environ. Contract ENV.B.2/SER/2010/0059.
McConnell, V., Walls, M., 2005. The Value of Open Space: Evidence from Studies of Nonmarket Benefits. Resour. Futur. 82.
McDonald, A.G., Bealey, W.J., Fowler, D., Dragosits, U., Skiba, U., Smith, R.I., Donovan, R.G., Brett, H.E., Hewitt, C.N., Nemitz, E., 2007. Quantifying the effect of urban tree planting on concentrations and depositions of PM10 in two UK conurbations. Atmos. Environ. 41, 8455–8467. doi:10.1016/j.atmosenv.2007.07.025
McHarg, I.L., 1969. Design with nature. American Museum of Natural History, New York.
Mell, I.C., Henneberry, J., Hehl-Lange, S., Keskin, B., 2013. Promoting urban greening: Valuing the development of green infrastructure investments in the urban core of Manchester, UK. Urban For. Urban Green. 12, 296–306. doi:10.1016/j.ufug.2013.04.006
Meulen, S. Van Der, Schasfoort, F., Horst, S. Van Der, Brugge, R. Van Der, Oostrom, N. Van, Altamirano, M., 2013. Vergoedingen voor ecosysteemdiensten.
Mihaylov, M., Perkins, D.D., 2014. Community place attachment and its role in social capital development, in: Place Attachment: Advances in Theory, Methods and Applications. pp. 61–74.
Morales-Torres, A., Escuder-Bueno, I., Andrés-Doménech, I., Perales-Momparler, S., 2016. Decision support tool for energy-efficient, sustainable and integrated urban stormwater management. Environ. Model. Softw. 84, 518–528. doi:10.1016/j.envsoft.2016.07.019
Mullaney, J., Lucke, T., Trueman, S.J., 2015. A review of benefits and challenges in growing street trees in paved urban environments. Landsc. Urban Plan. 134, 157–166. doi:10.1016/j.landurbplan.2014.10.013
Naidoo, R., Balmford, A., Ferraro, P.J., Polasky, S., Ricketts, T.H., Rouget, M., 2006. Integrating economic costs into conservation planning. Trends Ecol. Evol. 21, 681–687. doi:10.1016/j.tree.2006.10.003
Narayan, S., Beck, M.W., Reguero, B.G., Losada, I.J., van Wesenbeeck, B., Pontee, N., Sanchirico, J.N., Ingram, J.C., Lange, G.-M., Burks-Copes, K.A., 2016. The effectiveness, costs and coastal protection benefits of natural and nature-based defences. PLoS One 11, e0154735. doi:10.1371/journal.pone.0154735
Nassauer, J.I., Raskin, J., 2014. Urban vacancy and land use legacies: A frontier for urban ecological research, design, and planning. Landsc. Urban Plan. 125, 245–253. doi:10.1016/j.landurbplan.2013.10.008
Natural England, 2014. Access to Nature: inspiring people to engage with their natural environment. London, UK.
Neckles, H.A., Dionne, M., 2000. Regional standards to identify and evaluate tidal wetland restoration in the Gulf of Maine. Wells, ME.
Nesshöver, C., Assmuth, T., Irvine, K.N., Rusch, G.M., Waylen, K.A., Delbaere, B., Haase, D., Jones-Walters, L., Keune, H., Kovacs, E., Krauze, K., Külvik, M., Rey, F., van Dijk, J., Vistad, O.I., Wilkinson, M.E., Wittmer, H., 2016. The science, policy and practice of nature-based solutions: An interdisciplinary perspective. Sci. Total Environ. doi:10.1016/j.scitotenv.2016.11.106
Niemelä, J., 2014. Ecology of urban green spaces: The way forward in answering major research questions. Landsc. Urban Plan. 125, 298–303. doi:10.1016/j.landurbplan.2013.07.014
Nowak, D.J., Crane, D.E., Stevens, J.C., Hoehn, R.E., Walton, J.T., 2008. A ground-based method of assessing urban forest structure and ecosystem services 34, 347–358.
Nowak, D.J., Hirabayashi, S., Bodine, A., Hoehn, R., 2013. Modeled PM2.5 removal by trees in ten U.S. cities and associated health effects. Environ. Pollut. 178, 395–402. doi:10.1016/j.envpol.2013.03.050
Nussbaum, M.C., 2011. Creating Capabilities, in: The Human Development Approach. pp. 17–45. doi:10.2307/j.ctt2jbt31
OECD, 2008. Competitive Cities and Climate Change. OECD, Paris, France.
OECD, 2013. Green Growth in Cities. OECD publishing. doi:10.1787/9789264195325-en
Oke, T.R., 1973. City size and the urban heat island. Atmos. Environ. 7, 769–779. doi:10.1016/0004-6981(73)90140-6
Orhel, R.L., Register, K.M., 2006. Volunteer Estuary Monitoring: A Methods Manual. Second Edition. Washington, DC, USA.
Palomo, I., Felipe-Lucia, M.R., Bennett, E.M., Martín-López, B., Pascual, U., 2016. Disentangling the pathways and effects of ecosystem service co-production. Advances in Ecological Research. 54, 245-283. http://dx.doi.org/10.1016/bs.aecr.2015.09.003
Pataki, D.E., Alig, R.J., Fung, A.S., Golubiewski, E., Kennedy, C.A., Al., E., 2006. Urban ecosystems and the North American carbon

cycle. Glob. Chang. Biol. 12, 1–11.
Pataki, D.E., Carreiro, M.M., Cherrier, J., Grulke, N.E., Jennings, V., Pincetl, S., Pouyat, R. V., Whitlow, T.H., Zipperer, W.C., 2011. Coupling biogeochemical cycles in urban environments: Ecosystem services, green solutions, and misconceptions. Front. Ecol. Environ. 9, 27–36. doi:10.1890/090220
Pauleit, S., Duhme, F., 2000. Assessing the environmental performance of land cover types for urban planning. Landsc. Urban Plann 52, 1–20.
Pearce, D., Moran, D., Biller, D., 2002. Handbook of Biodiversity Valuation: A Guide for Policy Makers 1–156. OECD, Danvers, MA. doi:10.1787/9789264175792-en
Perez, G., Rincon, L., Vila, A., Gonzalez, J.M., Cabeza, L.F., 2011. Behaviour of green facades in Mediterranean Continental climate. Energy Convers. Manag. 52, 1861–1867. doi:10.1016/j.enconman.2010.11.008
Perez, A.C., Grafton, B., Mohai, P., Hardin, R., Hintzen, K., Orvis, S., 2015. Evolution of the environmental justice movement: Activism, formalization and differentiation. Environ. Res. Lett. 10, 105002. doi:10.1088/1748-9326/10/10/105002
Pérez Soba, M., P.A. Harrison, A.C. Smith, G. Simpson, M. Uiterwijk, L. Miguel Ayala, F. Archaux, T. Erős, N. Fabrega Domenech, Á.I. György, R. Haines-Young, S. Li, E. Lommelen, L. Meiresonne, L. Mononen, E. Stange, F. Turkelboom, C. Veerkamp and V. Wyllie de Echeverria, 2015. Database and operational classification system of ecosystem service – natural capital relationships. Deliverable 3.1 of the EU FP7 OpenNESS project. Available online at http://www.openness-project.eu/sites/default/files/OpenNESSD3_1_VSep2016.pdf.
Perkins, H.E., 2010. Measuring love and care for nature. J. Environ. Psychol. 30, 455–463. doi:10.1016/j.jenvp.2010.05.004
Petrosillo, I., Zurlini, G., Grato, E., Zaccarelli, N., 2006. Indicating fragility of socio-ecological tourism-based systems. Ecol. Indic. 6, 104–113.
Pinho, P., Correia, O., Lecoq, M., Munzi, S., Vasconcelos, S., Gonçalves, P., Rebelo, R., Antunes, C., Silva, P., Freitas, C., Lopes, N., Santos-Reis, M., Branquinho, C., 2016. Evaluating green infrastructure in urban environments using a multi-taxa and functional diversity approach. Environ. Res. 147, 601–610. doi:10.1016/j.envres.2015.12.025
Pino, J., Marull, J., 2012. Ecological networks: are they enough for connectivity conservation? A case study in the Barcelona Metropolitan Region (NE Spain). Land Use Policy 29, 684–690.
Pirnat, J., Hladnik, D., 2016. Connectivity as a tool in the prioritization and protection of sub-urban forest patches in landscape conservation planning. Landsc. Urban Plan. 153, 129–139. doi:10.1016/j.landurbplan.2016.05.013
Piwowarczyk, J., Kronenberg, J., Dereniowska, M.A., 2013. Marine ecosystem services in urban areas: Do the strategic documents of Polish coastal municipalities reflect their importance? Landsc. Urban Plan. 109, 85–93. doi:10.1016/j.landurbplan.2012.10.009
Plieninger, T., Bieling, C., Fagerholm, N., Byg, A., Hartel, T., Hurley, P., López-Santiago, C.A., Nagabhatla, N., Oteros-Rozas, E., Raymond, C.M., van der Horst, D., Huntsinger, L., 2015. The role of cultural ecosystem services in landscape management and planning. Curr. Opin. Environ. Sustain. 14, 28–33. doi:10.1016/j.cosust.2015.02.006
Polat, A.T., Akay, A., 2015. Relationships between the visual preferences of urban recreation area users and various landscape design elements. Urban For. Urban Green. 14, 573–582. doi:10.1016/j.ufug.2015.05.009
Potschin, M., Kretsch, C., Haines-Young, R., Furman, E., Berry, P., Baró, F., 2016. Nature-based solutions, OpenNESS Ecosystem Service Reference Book. http://www.openness-project.eu/library/reference-book
Pregnolato, M., Ford, A., Robson, C., Glenis, V., Barr, S., Dawson, R., 2016. Assessing urban strategies for reducing the impacts of extreme weather on infrastructure networks. R. Soc. Open Sci. 3. doi:10.1098/rsos.160023
Project Dirt, 2013. Angel Community Garden. https://projectdirt.com/project/11261/
Pullin, A., Frampton, G., Jongman, R., Kohl, C., Livoreil, B., Lux, A., Pataki, G., Petrokofsky, G., Podhora, A., Saarikoski, H., Santamaria, L., Schindler, S., Sousa-Pinto, I., Vandewalle, M., Wittmer, H., 2016. Selecting appropriate methods of knowledge synthesis to inform biodiversity policy. Biodivers. Conserv. 25, 1285–1300. doi:10.1007/s10531-016-1131-9
Raimondo, F., Trifilo, P., Lo Gullo, M. A., Andri, S., Savi, T., Nardini, A., 2015. Plant performance on Mediterranean green roofs: Interaction of species-specific hydraulic strategies and substrate water relations. AoB Plants 7, plv007. doi:10.1093/aobpla/plv007
Ramalho, C.E., Hobbs, R.J., 2012. Time for a change: Dynamic urban ecology. Trends Ecol. Evol. 27, 179–188. doi:10.1016/j.tree.2011.10.008
Randall, T., 2015. The smartest building in the world: Inside the connected future of architecture. http://www.bloomberg.com/features/2015-the-edge-the-worlds-greenest-building/.
Raymond, C.M., Bryan, B.A., MacDonald, D.H., Cast, A., Strathearn, S., Grandgirard, A., Kalivas, T., 2009. Mapping community values for natural capital and ecosystem services. Ecol. Econ. 68, 1301–1315. doi:10.1016/j.ecolecon.2008.12.006
Raymond, C.M., Brown, G., Weber, D., 2010. The measurement of place attachment: Personal, community and environmental connections. J. Environ. Psychol. 30, 422–434. doi:10.1016/j.jenvp.2010.08.002
Raymond, C.M., Kenter, J.O., Plieninger, T., Turner, N.J., Alexander, K.A., 2014. Comparing instrumental and deliberative paradigms underpinning the assessment of social values for cultural ecosystem services. Ecol. Econ. 107, 145–156. doi:http://dx.doi.org/ 10.1016/j.ecolecon.2014.07.033
Raymond, C.M., Calfapietra, C., Breil, M., Kabisch, N., Razvan Nita, M., Berry, P., Cardinaletti, M., Lovinger, L., Basnou, C., de Bel, M., Enzi, V., Geneletti, D., Monteiro, A., Robrecht, H., Frantzeskaki, N., 2016a. Protocol for the design of an impact evaluation framework that can be used by the demonstrated nature-based solutions projects. EKLIPSE, Brussels. Available online at http://www.eklipse-mechanism.eu/ongoing_processes
Raymond, C.M., Gottwald, S., Kuoppa, J., Kyttä, M., 2016b. Integrating multiple elements of environmental justice into urban blue space planning using public participation geographic information systems. Landsc. Urban Plan. 153, 198–208. doi:10.1016/j.landurbplan.2016.05.005
Reed, M.S., 2008. Stakeholder participation for environmental management: A literature review. Biol. Conserv. 141, 2417–2431.

doi:10.1016/j.biocon.2008.07.014
Reed, M.S., Graves, A., Dandy, N., Posthumus, H., Hubacek, K., Morris, J., Prell, C., Quinn, C.H., Stringer, L.C., 2009. Who's in and why? A typology of stakeholder analysis methods for natural resource management. J. Environ. Manage. 90, 1933–49. doi:10.1016/j.jenvman.2009.01.001
Reyers, B., Nel, J.L., O'Farrell, P.J., Sitas, N., Nel, D.C., 2015. Navigating complexity through knowledge coproduction: Mainstreaming ecosystem services into disaster risk reduction. Proc. Natl. Acad. Sci. 112, 201414374. doi:10.1073/pnas.1414374112
Rizwan, A.M., Dennins, L.Y.C., Liu, C., 2008. A review on the generation, determination and mitigation of Urban Heat Island. J. Environ. Sci. 20, 120–128. doi:10.1016/S1001-0742(08)60019-4
Roe, J.J., Ward Thompson, C., Aspinall, P.A., Brewer, M.J., Duff, E.I., Miller, D., Mitchell, R., Clow, A., 2013. Green space and stress: Evidence from cortisol measures in deprived urban communities. Int. J. Environ. Res. Public Health 10, 4086–4103. doi:10.3390/ijerph10094086
Romijn, G., Renes, G., 2013. Algemene leidraad voor maatschappelijke kosten-batenanalyse. CPB, The Netherlands. https://www.cpb.nl/publicatie/algemene-leidraad-voor-maatschappelijke-kosten-batenanalyse
Rutt, R.L., Gulsrud, N.M., 2016. Green justice in the city: A new agenda for urban green space research in Europe. Urban For. Urban Green. 19, 123–127. doi:10.1016/j.ufug.2016.07.004
Saraev, V. 2012. Economic benefits of greenspace: a critical assessment of evidence of net economic benefits. Forestry Commission Research Report. Forestry Commission, Edinburgh.
Scharf, B., Pitha, U., Enzi, V., 2012. Comparison of laboratory and in-field water storage properties of different green roofs and gravel roof. Copenhagen, Denmark, p. 1.
Schipperijn, J., Ekholm, O., Stigsdotter, U.K., Toftager, M., Bentsen, P., Kamper- Jørgensen, F., Randrup, T.B., 2010. Factors influencing the use of green space: Results from a Danish national representative survey. Landsc. Urban Plan. 95, 130–137.
Schlosberg, D., 2007. Defining Environmental Justice: Theories, Movements, and Nature, Oxford University Press, Oxford, UK.
Scholte, S.S.K., van Teeffelen, A.J.A., Verburg, P.H., 2015. Integrating socio-cultural perspectives into ecosystem service valuation: A review of concepts and methods. Ecol. Econ. 114, 67–78. doi:10.1016/j.ecolecon.2015.03.007
Schönach, P., 2014. Historical paths of environmental injustice: A century of placing industrial facilities in Helsinki, Finland. Local Environ. 21, 397–413. doi:10.1080/13549839.2014.985641
Seavitt Nordenson, C., Alexander, K., Alessi, D., Sands, E., 2015. Shifting Sands. Sedimentary cycles for Jamaica Bay.
Sen, A., 2005. Human Rights and Capabilities. J. Hum. Dev. 6, 151–166. doi:10.1080/14649880500120491
Sepe, M., 2013. Urban history and cultural resources in urban regeneration: A case of creative waterfront renewal. Plan. Perspect. 28, 595–613. doi:10.1080/02665433.2013.774539
Setälä, H., Viippola, V., Rantalainen, A.-L., Pennanen, A., Yli-Pelkonen, V., 2013. Does urban vegetation mitigate air pollution in northern conditions? Environ. Pollut. 183, 104–12. doi:10.1016/j.envpol.2012.11.010
Setten, G., Stenseke, M., Moen, J., 2012. Ecosystem services and landscape management: Three challenges and one plea. Int. J. Biodivers. Sci. Ecosyst. Serv. Manag. 8, 305–312. doi:10.1080/21513732.2012.722127
Shanahan, D.F., Lin, B.B., Gaston, K.J., Bush, R., Fuller, R.A., 2014. Socio-economic inequalities in access to nature on public and private lands: A case study from Brisbane, Australia. Landsc. Urban Plan. 130, 14–23. doi:10.1016/j.landurbplan.2014.06.005
Sheppard, S.R.J., 2005. Landscape visualisation and climate change: The potential for influencing perceptions and behaviour. Environ. Sci. Policy 8, 637–654. doi:10.1016/j.envsci.2005.08.002
Shishegar, N., 2015. The impacts of green areas on mitigating urban heat island effect: A review. The International Journal of Environmental Sustainability. 9, 119-130.
Shuster, E., Doerr, P., 2015. A guide for incorporating ecosystem service valuation into coastal restoration projects. The Nature Conservancy, New Jersey Chapter. Delmont, NJ.
Soares, A.L., Rego, F.C., McPherson, E.G., Simpson, J.R., Peper, P.J., Xiao, Q., 2011. Benefits and costs of street trees in Lisbon, Portugal. Urban For. Urban Green. 10, 69–78. doi:10.1016/j.ufug.2010.12.001
Speak, A.F., Rothwell, J.J., Lindley, S.J., Smith, C.L., 2012. Urban particulate pollution reduction by four species of green roof vegetation in a UK city. Atmos. Environ. 61, 283–293. doi:10.1016/j.atmosenv.2012.07.043
Specht, K., Zoll, F., Siebert, R., 2016. Application and evaluation of a participatory "open innovation" approach (ROIR): The case of introducing zero-acreage farming in Berlin. Landsc. Urban Plan. 151, 45–54. doi:10.1016/j.landurbplan.2016.03.003
Stafford, M., Bartley, M., Sacker, A., Marmot, M., Wilkinson, R., Boreham, R., Thomas, R., 2003. Measuring the social environment: Social cohesion and material deprivation in English and Scottish neighbourhoods. Environ. Plan. A 35, 1459–1475. doi:10.1068/a35257
Stark, J., Plancke, Y., Ides, S., Meire, P., Temmerman, S., 2016. Coastal flood protection by a combined nature-based and engineering approach: Modeling the effects of marsh geometry and surrounding dikes. Estuar. Coast. Shelf Sci. 175, 34–45. doi:10.1016/j.ecss.2016.03.027
Strauss, A.L., Corbin, J., 1990. Basics of Qualitative Research Techniques and Procedures for Developing Grounded Theory . Sage, Thousand Oaks.
Sugiyama, T., Ward Thompson, C., 2007. Older people's health, outdoor activity and supportiveness of neighbourhood environments. Landsc. Urban Plan. 83, 168–175. doi:10.1016/j.landurbplan.2007.04.002
Tallis, M., Taylor, G., Sinnett, D., Freer-Smith, P., 2011. Estimating the removal of atmospheric particulate pollution by the urban tree canopy of London under current and future environments. Landsc. Urban Plan. 103, 129–138. doi:10.1016/j.landurbplan.2011.07.003
Tallon, A., 2013. Urban Regeneration in the UK. Routledge, Abingdon, Oxon.
Tamosiunas, A., Grazuleviciene, R., Luksiene, D., Dedele, A., Reklaitiene, R., Baceviciene, M., Vencloviene, J., Bernotiene, G., Radisauskas, R., Malinauskiene, V., Milinaviciene, E., Bobak, M., Peasey, A., Nieuwenhuijsen, M.J., 2014. Accessibility and use

of urban green spaces, and cardiovascular health: Findings from a Kaunas cohort study. Environ. Heal. 13, 20. doi:10.1186/1476-069X-13-20
TEEB – The Economics of Ecosystems and Biodiversity (2011). TEEB Manual for Cities: Ecosystem Services in Urban Management. www.teebweb.org
Tengö, M., Brondizio, E.S., Elmqvist, T., Malmer, P., Spierenburg, M., 2014. Connecting diverse knowledge systems for enhanced ecosystem governance: the multiple evidence base approach. Ambio 43, 579–91. doi:10.1007/s13280-014-0501-3
Tiwary, A., Sinnett, D., Peachey, C., Chalabi, Z., Vardoulakis, S., Fletcher, T., Leonardi, G., Grundy, C., Azapagic, A., Hutchings, T.R., 2009. An integrated tool to assess the role of new planting in PM10 capture and the human health benefits: A case study in London. Environ. Pollut. 157, 2645–53. doi:10.1016/j.envpol.2009.05.005
Tyler, P., Warnock, C., Provins, A., Lanz, B., 2013. Valuing the benefits of urban regeneration. Urban Stud. 50, 169–190. doi:10.1177/0042098012452321
Tyrväinen, L., Miettinen, A., 2000. Property prices and urban forest amenities. J. Environ. Econ. Manage. 39, 205–223. doi:10.1006/jeem.1999.1097
Ugolini, F., Massetti, L., Sanesi, G., Pearlmutter, D., 2015. Knowledge transfer between stakeholders in the field of urban forestry and green infrastructure: Results of a European survey. Land Use Policy 49, 365–381. doi:10.1016/j.landusepol.2015.08.019
Uittenbroek, C.J., Janssen-Jansen, L.B., Runhaar, H.A.C., 2013. Mainstreaming climate adaptation into urban planning: Overcoming barriers, seizing opportunities and evaluating the results in two Dutch case studies. Reg. Environ. Chang. 13, 399–411. doi:10.1007/s10113-012-0348-8
Ulrich, R.S., 1984. View through a window may influence recovery from surgery. Science 224, 420–421.
Ulrich, R.S., 2002. Health benefits of gardens in hospitals. Plants for People Conference Paper at the International Exhibition Floriade.
UNFCCC, 2016. Report of the Conference of the Parties on its twenty-first session, held in Paris from 30 November to 13 December 2015. http://unfccc.int/resource/docs/2015/cop21/eng/10.pdf
Uzzell, D., Pol, E., Badenas, D., 2002. Place identification, social cohesion, and environmental sustainability. Environ. Behav. 34, 26–53. doi:10.1177/0013916502034001003
van den Berg, A.E., Maas, J., Verheij, R. a, Groenewegen, P.P., 2010. Green space as a buffer between stressful life events and health. Soc. Sci. Med. 70, 1203–10. doi:10.1016/j.socscimed.2010.01.002
van den Berg, M., Wendel-Vos, W., Van Poppel, M., Kemper, H., Van Mechelen, W., Maas, J., 2015. Health benefits of green spaces in the living environment: A systematic review of epidemiological studies. Urban For. Urban Green. 14, 806–816. doi:10.1016/j.ufug.2015.07.008
van Veelen, R., Otten, S., Cadinu, M., Hansen, N., 2015. An integrative model of social identification: self-stereotyping and self-anchoring as two cognitive pathways. Pers. Soc. Psychol. Rev. 1088868315576642-. doi:10.1177/1088868315576642
van Vuuren, D.P., Isaac, M., Kundzewicz, Z.W., Arnell, N., Barker, T., Criqui, P., Berkhout, F., Hilderink, H., Hinkel, J., Hof, A., Kitous, A., Kram, T., Mechler, R., Scrieciu, S., 2011. The use of scenarios as the basis for combined assessment of climate change mitigation and adaptation. Glob. Environ. Chang. 21, 575–591.
Vandergert, P., Collier, M., Kampelmann, S., Newport, D., 2015. Blending adaptive governance and institutional theory to explore urban resilience and sustainability strategies in the Rome metropolitan area, Italy. Int. J. Urban Sustain. Dev. 3138, 1–18. doi:10.1080/19463138.2015.1102726
Vierikko, K., Niemelä, J., 2016. Bottom-up thinking—Identifying socio-cultural values of ecosystem services in local blue–green infrastructure planning in Helsinki, Finland. Land Use Policy 50, 537–547. doi:10.1016/j.landusepol.2015.09.031
Von Döhren, P., Haase, D., 2015. Ecosystem disservices research: a review of the state of the art with a focus on cities. Ecol. Indic. 52, 2015. doi:http://dx.doi.org/10.1016/j. ecolind.2014.12.027
Vos, P.E.J., Maiheu, B., Vankerkom, J., Janssen, S., 2013. Improving local air quality in cities: To tree or not to tree? Environ. Pollut. 183, 113–122. doi:10.1016/j.envpol.2012.10.021
Voyer, M., Dreher, T., Gladstone, W., Goodall, H., 2013. Who cares wins: The role of local news and news sourcesin influencing community responses to maxine protected areas. Ocean Coast. Manag. 85, 29–38.
Vries, S. de, Verheij, R.A., Groenewegen, P.P., Spreeuwenberg, P., 2003. Natural environments — healthy environments? An exploratory analysis of the relationship between greenspace and health. Environ. Plan. A 35, 1717 – 1731.
Walker, B., Holling, C.S., Carpenter, S.R., Kinzig, A., 2004. Resilience, adaptability and transformability in social–ecological systems. Ecol. Soc. 9. doi:http://www.ecologyandsociety.org/vol9/iss2/art5/
Wang, D., Brown, G., Liu, Y., Mateo-Babiano, I., 2015a. A comparison of perceived and geographic access to predict urban park use. Cities 42, 85–96. doi:10.1016/j.cities.2014.10.003
Wang, Y., Bakker, F., de Groot, R., Wortche, H., Leemans, R., 2015b. Effects of urban trees on local outdoor microclimate: synthesizing field measurements by numerical modelling. Urban Ecosyst. doi:10.1007/s11252-015-0447-7
Wang, Y., Berardi, U., Akbari, H., 2016. Comparing the effects of urban heat island mitigation strategies for Toronto, Canada. Energy Build. 114, 2–19. doi:10.1016/j.enbuild.2015.06.046
Wansborough, M., Mageean, A., 2000. The role of urban design in cultural regeneration. J. Urban Des. 5, 181–197.
Ward Thompson, C., Roe, J., Aspinall, P., Mitchell, R., Clow, A., Miller, D., 2012. More green space is linked to less stress in deprived communities: Evidence from salivary cortisol patterns. Landsc. Urban Plan. 105, 221–229. doi:10.1016/j.landurbplan.2011.12.015
Williams, D., Brown, J., 2012. Learning Gardens and Sustainability Education. Routledge, London.
Wolch, J.R., Byrne, J., Newell, J.P., 2014. Urban green space, public health, and environmental justice: The challenge of making cities "just green enough." Landsc. Urban Plan. 125, 234–244. doi:10.1016/j.landurbplan.2014.01.017
Wong, P.P., Losada, I.J., Gattuso, J.-P., Hinkel, J., Khattabi, A., McInnes, K.L., Saito, Y., Sallenger, A., 2014. Coastal systems and low-lying areas, in: Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L.,

Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R., White, L.L. (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel of Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 361–409.

Xiao, Q., McPherson, E.G., 2002. Rainfall interception by Santa Monica's municipal urban forest. Urban Ecosyst. 6, 291–302. doi:10.1023/B

Xu, Z., FitzGerald, G., Guo, Y., Jalaludin, B., Tong, S., 2016. Impact of heatwave on mortality under different heatwave definitions: A systematic review and meta-analysis. Environ. Int. 89–90, 193–203. doi:10.1016/j.envint.2016.02.007

Yepsen, M., Moody, J., Schuster, E., 2016. A framework for developing monitoring plans for coastal wetland restoration and living shoreline projects in New Jersey. Report prepared by the New Jersey Measures and Monitoring Workgroup of the NJ Resilient Coastlines Initiative, with support from the NOAA National Oceanic and Atmospheric Administration (NOAA) Coastal Resilience (CRest) Grant program (NA14NOS4830006).

Yin, S., Shen, Z., Zhou, P., Zou, X., Che, S., Wang, W., 2011. Quantifying air pollution attenuation within urban parks: An experimental approach in Shanghai, China. Environ. Pollut. 159, 2155–2163. doi:10.1016/j.envpol.2011.03.009

Young, R., Zanders, J., Lieberknecht, K., Fassman-Beck, E., 2014. A comprehensive typology for mainstreaming urban green infrastructure. J. Hydrol. 519, 2571–2583. doi:10.1016/j.jhydrol.2014.05.048

Zajda, J., Majhanovich, S., Rust, V., 2007. Introduction: Education and social justice. Int. Rev. Educ. doi:10.1007/s11159-005-5614-2

Zheng, D., Ducey, M.J., Heath, L.S., 2013. Assessing net carbon sequestration on urban and community forests of northern New England, USA. Urban For. Urban Green. 12, 61–68. doi:10.1016/j.ufug.2012.10.003

Zinzi, M., Agnoli, S., 2011. Cool and green roofs. An energy and comfort comparison between passive cooling and mitigation urban heat island techniques for residential buildings in the Mediterranean region. Energy Build. 55, 66–76.

Appendix 1 – Summary of the Types of Indicators and Methods to Consider in NBS Impact Assessments

Challenge	Indicator description	Type of indicator (which determines the way it can be used for assessments)	Unit of measurement	Examples of method(s) of assessment for indicator	Geographic Scale					Temporal scale		
					Region	Metro-politan	Urban	Street	House	Short	Medium	Long
Ch 2	Economic benefit of reduction of stormwater to be treated in public sewerage system	Economic (Monetary)	Cost of sewerage treatment by volume (€/m3)	CBA: the avoided cost of run – off water in the sewerage treatment system can be used as one benefit created by the measure in a CBA (Xiao and Mc Pherson 2002; Soares et al. 2011; Deng et al. 2013))	•	•	•	•	•	•		
Ch 5	Reduced energy demand for heating and cooling	Economic (Monetary)	€ /kwh	With reference to a base line situation, the costs of energy not consumed (= saved) is accounted for as a benefit	•	•	•	•	•	•		
Ch 10	Jobs created	Economic (Non-monetary)	Number of jobs	CEA Number of jobs created from public employment records, number of jobs in specific sectors	•	•	•			•		
Ch 2	Nutrient abatement, abatement of pollutants	Environmental (physical)	% of mass removal	(laboratory) experiment measuring of water quality, estimation of biomass/abatement capacity across different vegetation types) Estimation of biomass across different vegetation types)	•					<	•	
Ch 5	Reduced energy demand for heating and cooling	Environmental (chemical) benefit	CO_2 emissions reduced	With reference to a base line situation, the energy not consumed can be accounted for as a reduction of CO_2 emissions	•	•	•	•	•	•	•	
Ch 1	Net carbon sequestration by urban forests (including GHG emissions from maintenance activities)	Environmental (chemical)	t C per ha $^{-1}$/year	Numerical methods calculating or estimating the interactions between vegetation and pollutants at the micro scale allometric equations that predict vegetation growth, Forest Inventory Analysis			•			<	•	•

Challenge	Indicator description	Type of indicator (which determines the way it can be used for assessments)	Unit of measurement	Examples of method(s) of assessment for indicator	Geographic Scale					Temporal scale		
					Region	Metro-politan	Urban	Street	House	Short	Medium	Long
Ch 5	Annual amount of pollutants captured and removed by vegetation	Environmental (chemical)		"Tiwary method", map air purification using spatially-explicit data on ecosystems types and characteristics (particularly LAI), and pollution distribution, Forest Inventory Analysis	•		•			<	•	•
Ch 2	Increased evapotranspiration	Environmental (physical)	ET	Estimation based of coefficients for plant types	•	•	•	•	•	•		
Ch 1, 2	Temperature reduction in urban areas	Environmental (physical)	min. and max C° / day	Measurement (modelling) of day and night mean max and min. temperatures, with respect to baseline values	•	•	•	•		•	•	
Ch 1, 2	Heatwave risks	Environmental (physical)	persons / ha	Number of persons living in areas with x of days above threshold day and night temperatures. Temperature thresholds defining risk are slightly varying across regions; source: local health information systems	•	•	•	•		<	•	
Ch1, 3, 6	Temperature	Environmental (physical)	(Changes) in mean and daily min and max temperatures (°C)	Measurements			•					
Ch 2	infiltration capacities	Environmental (physical)	mm/h	Surface and extent of flooded areas, analysis of soil and vegetation characteristics			•					
Ch 2	User values attached to green/blue areas	Social (benefits) (qualitative or monetized)	Qualitative or €	Mapping of user values using qualitative surveys on user preferences or contingent valuation	•	•	•	•	•			
Ch 6	Index of biodiversity	Environmental (biological)		Document and analysis of the best replicable practice of NBS with multidisciplinary teams, LIDAR, spatial analysis and ES mapping	•	•	•	•	•	<	•	
Ch 4	Number of users and public awareness	Social (benefits)	€, n of visitors/year	Contingent valuation method, , travel cost, counting visitors, qualitative approaches		•	•			<	•	•

Challenge	Indicator description	Type of indicator (which determines the way it can be used for assessments)	Unit of measurement	Examples of method(s) of assessment for indicator	Geographic Scale					Temporal scale		
					Region	Metro-politan	Urban	Street	House	Short	Medium	Long
Ch 4	% of accessible public green space per capita	Social (benefits)	m^2/person	GIS mapping and analysis, including nearest neighbour analysis						•		
Ch 4, 6	% of citizens living within a given distance from accessible public green space	Social (benefits)	persons	GIS mapping using network analysis in order to take into account existing barriers and access ways, statistics,	•	•	•	•	•	•		
Ch 8, 3	The availability and distribution of different types of parks and/or ecosystem services with respect to specific individual or household socioeconomic profiles and landscape design	Social (benefits)	e.g. mean distance (or time to reach) parks per inhabitant,.	Statistics GIS, definition of criteria for park types index for spatial distribution, network analysis using GIS for assessing accessibility of parks		•	•	•		•		
Ch 8	Security against violent assault, including indicators of crime by time of day	Social (physiological)	No of cases / year	Statistics and perceived levels of crime and safety.				•	•	•		
Ch 7, 8	Being able to participate effectively in political choices that govern one's life, including indicators on level and quality of public participation in environmental management	Social (physiological)	Number of connection/threshold for the definition of sufficient levels of connections	Actor-Network Analysis to better understanding how different stakeholders can bias management towards certain ecosystem services	•	•	•	•	•	<	•	
Ch 8	Structural aspects - family and friendship ties	Social (physiological)	Number of connection/threshold for the definition of sufficient levels of connections	Network analysis, survey, questionnaires and interviews, sampling				•				

Challenge	Indicator description	Type of indicator (which determines the way it can be used for assessments)	Unit of measurement	Examples of method(s) of assessment for indicator	Geographic Scale					Temporal scale		
					Region	Metro-politan	Urban	Street	House	Short	Medium	Long
Ch 9	Chronic stress and stress-related diseases as shown in cortisol levels	Cortisol slope and average cortisol levels	Social (physiological, benefits)	Measured through repeated salivary and/or hair cortisol sampling assessing effects of nature experiences through assignment of participants to particular exercises (walk in nature for a certain time) followed by psychological assessments and assessments of affective and cognitive functioning					•	<	•	
Ch 9	Increase in number and percentage of people being physically active ((min. 30 min 3 times per week)	Social (physiological, benefits)	Days with physical activity (n)	Questionnaires to ask for the number of days on which physical activity (of sufficient exertion to raise breathing rate) reached or exceeded 30 min (e.g. over the past 4 weeks) (self reporting)			•			<	•	
Ch 9	Reduced percentage of obese people and children,	Social (physiological, benefits)	%	Baseline needed for rate of obesity in population/eventually: reference to median city /regional /national percentage			•			<	•	
Ch 9	Reduction in overall mortality and increased lifespan	Social (physiological, benefits)	Number of deaths per 1000 individuals per year	Assessing effects of nature experiences through assignment of participants to particular exercises (walk in nature for a certain time) followed by psychological assessments and assessments of affective and cognitive functioning			•			<	•	
Ch 9	Reduction in number of cardiovascular morbidity and mortality events	Social (physiological, benefits)	Number of deaths per 1000 individuals per year; morbidity scores	Composite tools for measuring health and detailed psychometric testing			•			<	•	

< in some cases the indicator and/or method can be applied at this scale

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