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Nature-based Solutions
State of the Art
in EU-funded Projects

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Report

Research and
Innovation

Nature-Based Solutions: State of the Art in EU-funded Projects

European Commission

Directorate-General for Research and Innovation
Directorate C — Healthy Planet
Unit C3 — Climate and Planetary Boundaries

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Nature-Based Solutions
State of the Art in EU-funded Projects

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1. EXECUTIVE SUMMARY

1.1 The benefits and opportunities achievable using Nature-based Solutions (NBS) to address global and societal challenges have never been more relevant, important or urgently needed than now. Civilisations throughout the ages and across the planet have attempted to harness and utilise the power of nature, often with some success (in the short- or long-term) but also in ways that have caused great social, economic and environmental harm. However, human-induced global warming, climate change, environmental degradation and biodiversity loss – caused by pollution, lost or damaged natural habitats and urban sprawl – have all placed greater emphasis still on how our societies modify ecosystems, how we access their benefits or utilise their services, and how we protect ourselves from natural threats and disasters.

1.2 The EC defines NBS as "solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide 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." It further emphasizes that "nature-based solutions must benefit biodiversity and support the delivery of a range of ecosystem services."

1.3 This document summarises outcomes and evidence from the 'Valorisation of NBS Projects' initiative. EU research and innovation projects were scanned for results pertaining to NBS in key areas of policy implementation and development. The review was undertaken between November 2019 and May 2020 by six independent experts working in conjunction with EC staff, and supported by the network of Horizon 2020-funded NBS projects. Evidence from reviewed projects is framed within knowledge from the literature to give a fuller picture of the state of the art, showing how NBS can address a series of societal challenges. Contextualised information is provided on relevant policies, research results and key lessons. The resulting knowledge base includes figures and monetary values showing the relative cost-effectiveness of NBS and exploring how they support EU policy implementation.

1.4 Urban and rural communities alike rely heavily on 'conventional' infrastructures and systems for water supply, heating, lighting, drainage, cooling and other services such as places to meet or relax. The evidence is that several of these older systems and technologies may no longer be fit for purpose in the light of global changes whose impacts are being felt with increasing severity and frequency.

1.5 The urgency of these issues is accompanied by the need for rapid changes to deeply embedded and often highly valuable cultural heritage, legal frameworks, governance systems and professional and personal norms – which have developed gradually, i.e. over millennia. The networks and systems that have been built up are central to the ways in which we make agreements and handle disputes between people, communities, cities, regions and countries, or even continents. The scope for making mistakes is therefore huge, but the opportunities are also great, particularly if we innovate together and learn from one another.

1.6 NBS therefore offer a major chance for innovation, with possibilities to deliver lasting and tangible benefits across different social groups, in a range of environmental, economic and cultural settings, and in sharp contrast with the ways in which conventional, 'traditional' or 'grey' solutions are designed, constructed and managed over time. The present report describes evidence on many known advantages and successes with NBS. However, many NBS remain relatively novel solutions, presenting important challenges and unknowns in terms of their (co) design, operation, maintenance and how we organise their implementation. This report therefore concludes with an analysis of knowledge gaps, future research and innovation needs, and key policy development priorities, with a particular focus on Horizon Europe and the European Green Deal.

2. INTRODUCTION

2.1. PURPOSE OF THIS DOCUMENT

This report presents an analysis of the results and impacts of EU and international research and innovation projects on NBS. The EC's aims for this 'Valorisation of NBS Projects' report were to provide an evidence base to support the policy making process, integrating the outcomes of projects, and to strengthen the policy-research interface. Commissioned during the transition period between Horizon 2020 and Horizon Europe Framework Programmes, and simultaneously with the launch of the European Green Deal, this analysis is timely - given the growing recognition of the importance of NBS, and international momentum in their development and use to address increasingly urgent societal challenges (see section 3).

The departure point for this work was the EC's intention to review and evaluate the progress of key projects researching and innovating with NBS (and 'NBS-like' interventions), to better understand their application to address a range of core challenges faced by cities and regions. The findings and results of a broad range of European projects (primarily but not exclusively Horizon 2020 and FP7 projects) were considered alongside the wider literature, to help understand the state of the art. Based on this systematic analysis of project results, as well as of additional international research, this report provides key messages and recommendations for thematic policymaking as well as for EU R&I policy.

2.2. DEFINITIONS AND CONTEXT

There is growing recognition of the opportunities of implementing biodiverse NBS, which employ and enhance natural ecosystem properties and services to deliver sustainable, cost-effective, multi-purpose and flexible alternatives to address societal challenges.

The EC defines NBS as "solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide 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." It further emphasizes that "NBS must benefit biodiversity and support the delivery of a range of ecosystem services."

Relevant background material can be found at the EC's Research and Innovation website for the policy topic area on NBS. Key developments in the EC's NBS research and innovation agenda are outlined in Faivre et al (2017) and in Lafortezza (forthcoming). A further useful summary of key developments is available here following a recent workshop entitled 'Mobilizing up-scaling of NBS for climate change throughout 2020 and beyond'.

Other NBS definitions exist (e.g. IUCN) and are evolving along with related concepts in this dynamic field, such as ecosystem-based adaptation (see e.g. sections 5, 6 and 7), nature's contribution to people (section 8), natural water retention measures (section 5 and 6), and blue-green infrastructure (BGI, sections 4, 5 and 6). Many of these other terms for NBS-similar concepts or technologies have existed for some time. NBS can be considered as an 'umbrella term' for this wider range of concepts and practices (Nesshöver et al., 2017; Pauleit et al., 2017, see also Oppla). Figures 1 and 2 highlight the growth in publications referring to NBS, alongside relevant developments in policy and the contemporaneous evolution of related terms (e.g. Ruangpan et al., 2020, see also Fletcher et al., 2015). An implication of this valuable diversity is that there are not only important opportunities but also considerable challenges to integrate and frame knowledge from diverse NBS initiatives. The present valorisation project results help to fill this gap, alongside other EC initiatives supporting knowledge exchange, including the impact-evaluation framework for assessing the performance of NBS of EU science-policy-society mechanism EKLIPSE, and MAES, the Mapping and Assessment of Ecosystems and their Services (Maes et al., 2015), which provides data and indicators that can be used to develop relevant policies.

Figure 1. NBS publications and policy development timeline (Biodiversa, undated)

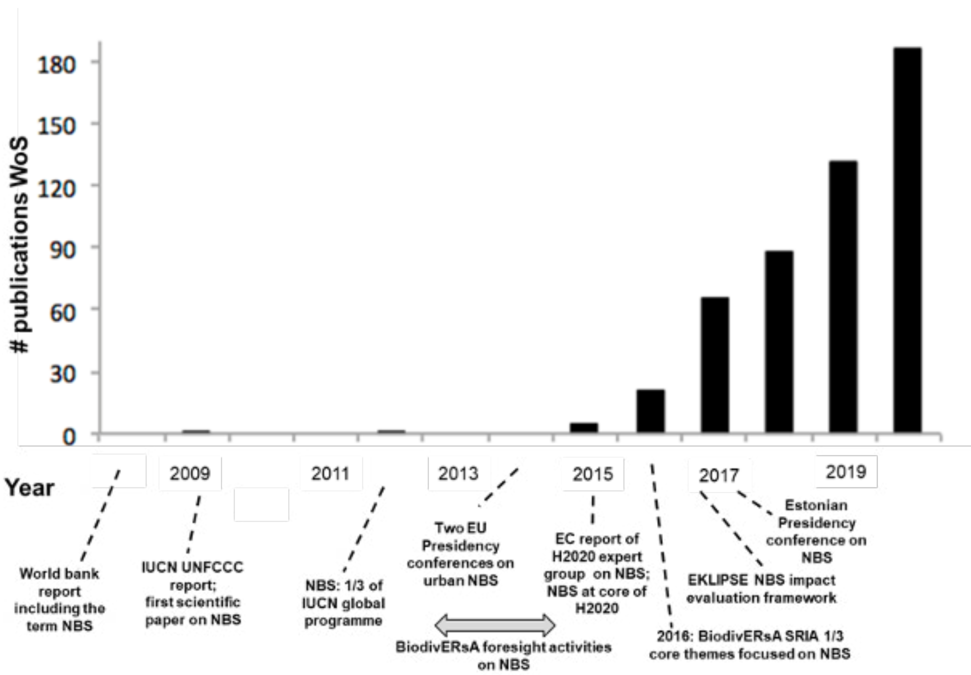
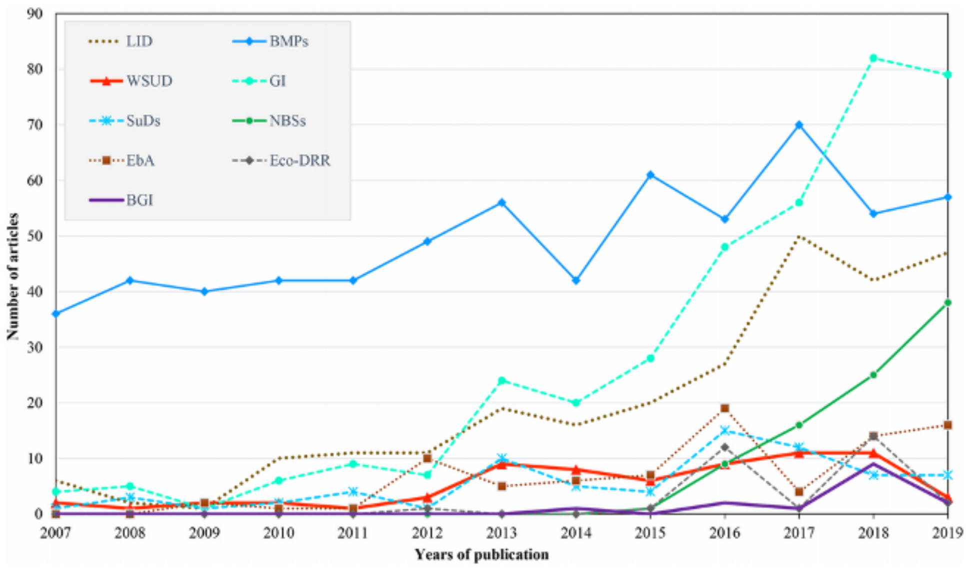


Figure 2. Trends in publication numbers: NBS & comparable approaches (Ruangpan et al., 2020)



Notes: LID - low impact development; WSUD – water sensitive urban design; SUDS – sustainable drainage systems; EbA – ecosystem-based adaptation; BGI – blue green infrastructure; BMPs – best management practices; GI – green infrastructure; NBS – nature-based solutions; Eco-DRR – eco-disaster risk reduction.

2.3. EU RESEARCH & INNOVATION POLICY AGENDA ON NBS & RE-NATURING

The EU Research and Innovation (R&I) policy agenda on NBS and Re-Naturing Cities aims to position the EU as leader in 'Innovating with nature' for more sustainable and resilient societies. The main goals of this EU policy agenda are to: (1) Enhance the framework conditions for NBS at EU policy level; (2) Develop an EU Research and Innovation Community for NBS; (3) Provide the evidence and knowledge base for NBS; (4) Advance the development, uptake and upscale of innovative NBS; and (5) Mainstream NBS within the international agenda. Further details of each strand of the policy agenda are summarised at the end of this section.

Considerable funding for the EC's NBS research and innovation agenda to underpin its policy topic area comes through H2020, which builds on invaluable results of the previous framework programme FP7. The relevant strands of the H2020 programme include projects with a total budget of €282m (Figure 4). Further investments in NBS research and innovation have been delivered through other EU instruments including COST, ERDF, LIFE+ and EIB's Natural Capital Financing Facility.

2.3.1. Enhancing the framework conditions for NBS at EU policy level

The EU's NBS R&I agenda contributes to knowledge creation and policy development in relevant areas, such as biodiversity, water management, climate change mitigation and adaptation, sustainable development, and disaster risk reduction. A search for the keywords 'nature-based', in the EC's 'consilium' register returns 20 results covering a vast array of key policy areas and legal developments. These range from conclusions on oceans and seas, through transition to circular economy and sustainable society, to climate and water diplomacy and global biodiversity convention developments.

Legislative and financial support for NBS cross-cuts several policy documents and sectors, and while Member State and EU policy instruments acknowledge NBS-related concepts, they seldomly contain quantitative and measurable targets relating to NBS placement and quality (Davis et al., 2018; Lafortezza, forthcoming). This indicates that further research, innovation and policy development is required to support work to embed NBS frameworks, policies and practices at various levels.

This report provides details of specific policy responses to societal and global challenges for six substantive topic areas (see sections 3-8 inclusive). NBS are now visible in European, global and national policies. However, their practical application cannot yet be classed as 'routine business'. NBS therefore provide an important opportunity for innovation, research, business development and trade.

2.3.2. Developing a European Research and Innovation Community for NBS

The 2015 Expert Group Report on NBS (EC, 2015a) was extremely influential in setting out the future direction and scope of forthcoming research and innovation in this topic area. It provided a springboard to establish a coherent EU R&I reference policy framework and agenda for NBS to address global societal challenges. Its long-term goal was to help position the EU as world leader in Research & Innovation and in the market of innovation with nature. Since then the above-described H2020 calls and projects addressing NBS themes (Figure 4) have been complemented by demonstrations and best practice exchanges funded through the territorial cooperation programmes (e.g. Interreg Europe), COST actions and other projects funded by the European Structural & Investment Funds (ESIF).

The FP7 Programme, while not explicitly addressing NBS, generated knowledge and expertise in green infrastructure (GI), ecosystem services, and the multiple benefits of ecosystem-based approaches used to address societal challenges. Thus there is an invaluable heritage and community in research and innovation exploring NBS-type approaches to a range of themes including climate change adaptation; systemic approaches to urban resilience and sustainability; innovative land-use planning; citizen participation and co-creation. Each has delivered tools, knowledge, publications and context-specific analyses providing useful lessons for NBS implementation (e.g. enabling factors and successful responses to obstacles).

A useful indication of the extent of the community involved in NBS research and innovation is given by the number of participants involved in proposals, as well as in funded projects. At the time of writing this report (April 2020), for 11 call areas relating to NBS, in total 28 projects were funded, but nearly 300 proposals were received. Beneficiaries in projects funded through those calls numbered 649, whereas the total number of organisations listed all proposals including unsuccessful ones was a staggering 4,014 partners (unique individual partner organisations, i.e. no double-counting of partners submitting bids across multiple calls). EC funds sought in bids totalled €17,872 million, with €243 million being awarded. H2020 calls for proposals on NBS have been oversubscribed. Since this report was written, several new projects have been awarded, with further funding committed; these calls have also been extremely popular amongst proposers (see Fig 4).

Figure 3. How NBS can address the SDGs. Examples from the EU (Faivre et al., 2017)

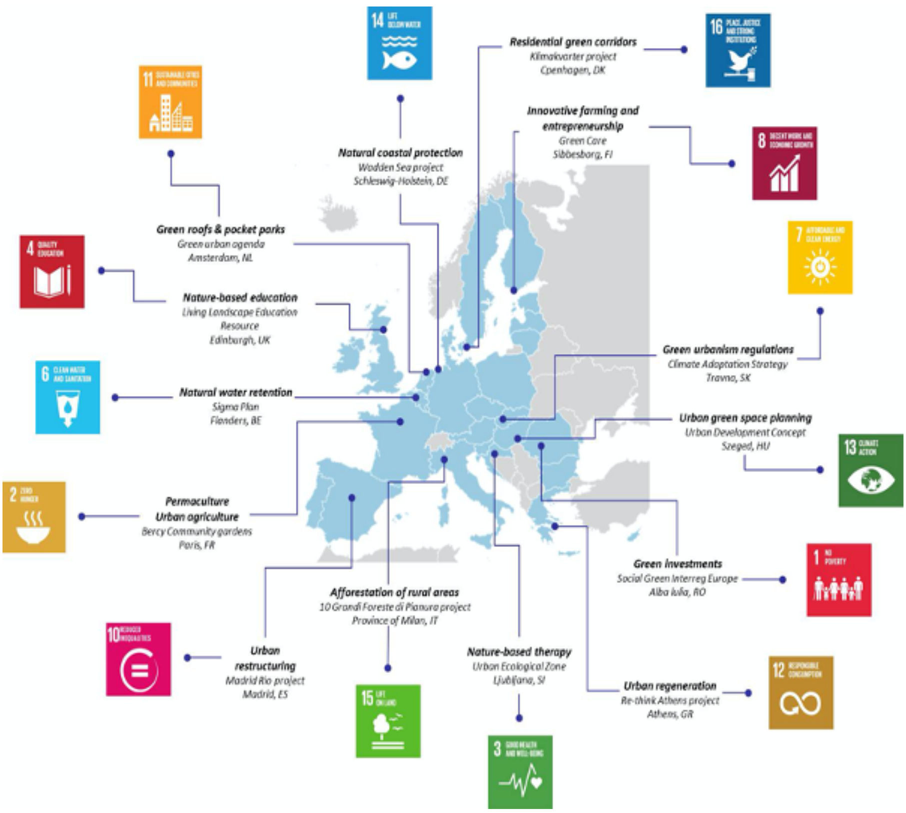


Figure 4. The portfolio of NBS projects in Horizon 2020

CALL TOPIC SCC-02-2016-2017
Demonstrating innovative nature-based solutions in cities

PROJECT NAME	EU CONTRIBUTION (in EUR)
2017-2022	
Connecting Nature	11 394 282
GrowGreen	11 224 058
UNaLab	12 768 932
URBAN GreenUP	13 970 642
2018-2023	
CLEVER Cities	14 214 661
EdiCitNet	11 254 913
proGIreg	10 432 512
URBiNAT	13 019 300
Total	**98 279 300**

CALL TOPIC SC5-08–2017
Large-scale demonstrators on nature-based solutions for hydro-meteorological risk reduction

PROJECT NAME 2018-2023	EU CONTRIBUTION (in EUR)
PHUSICOS	9 472 200
RECONECT	13 520 690
OPERANDUM	12 257 343
Total	**35 250 233**

CALL TOPIC LC-CLA-11-2020
Innovative NBS for carbon neutral cities and improved air quality

PROJECT NAME 2021-...	EU CONTRIBUTION (in EUR)
Project A	~ 10 000 000
Project B	~ 10 000 000
Project C	~ 10 000 000
Total	**30 000 000**

CALL TOPIC SCC-03-2016
New governance, business, financing models and economic impact assessment tools for sustainable cities with nature-based solutions (urban re-naturing)

PROJECT NAME 2016-2020	EU CONTRIBUTION (in EUR)
NATURVATION	7 797 878
Nature4Cities	7 499 981
Total	**15 297 859**

CALL TOPIC SC5-09–2016
Operationalising insurance value of ecosystems

PROJECT NAME 2016-2020	EU CONTRIBUTION (in EUR)
NAIAD	4 994 370

CALL TOPIC SC5-13-2018-2019
International cooperation on sustainable urbanisation: NBS for restoration and rehabilitation of urban ecosystems

EU- CHINA RROJECT NAME 2019-2023	EU CONTRIBUTION (in EUR)
REGREEN	4 996 172
CLEARING HOUSE	4 986 464
EU- CELAC 2020-2024	
CONEXUS	4 999 940
INTERLACE	5 476 165
Total	**20 458 741**

CALL TOPIC SC5-27-2020
Enhanced NBSfor water security and ecological quality in cities

PROJECT NAME 2021-...	EU CONTRIBUTION (in EUR)
Project A	~ 5 000 000
Project B	~ 5 000 000
Total	**10 000 000**

CALLS: MULTISTAKEHOLDER DIALOGUE PLATFORM FOR NBS

PROJECT NAME		EU CONTRIBUTION (in EUR)
ThinkNature	2016-2019	2 974 164
NetworkNature	2020-2023	2 189 834
Total		**5 163 998**

RESEARCH PROJECTS FUNDED BY OTHER H2020 CALLS

CALL TOPIC SC5-14-2019
Improving well-being and health in cities

PROJECT NAME 2020-2024	EU CONTRIBUTION (in EUR)
EUPOLIS	9 995 189
GO GREEN ROUTES	10 485 804
IN-HABIT	10 621 931
VARCITIES	10 115 469
Total	**41 218 393**

CALL TOPIC LC-CLA-06-2019
Inter-relations between climate change, biodiversity and ecosystem services

PROJECT NAME 2020-2024	EU CONTRIBUTION (in EUR)
DRYvER	6 702 008
FutureMARES	8 555 905
MaCoBioS	6 980 657
PONDERFUL	6 993 407
Total	**29 231 977**

2.3.3. Providing the evidence and knowledge base for NBS

Topic areas addressed by specific Work Programmes within H2020 covering NBS themes[1], which provided support to the projects that are the main subject of focus of this analysis, are illustrated in Figure 4 (see also Annex 4). They include:

- Call Topic SCC-03-2016: New governance, business, financing models and economic impact assessment tools for sustainable cities with nature-based solutions / urban re-naturing (2016-2020 - two projects).
- Call Topic SC5-09–2016: Operationalising insurance value of ecosystems (2016-2020 – one project).
- Call Topics SCC-02-2016-2017: Demonstrating innovative nature-based solutions in cities (2017-2022 - four projects; 2018-2023 - four projects).
- Call Topic SC5-08–2017: Large-scale demonstrators on nature-based solutions for hydro-meteorological risk reduction (2018-2023 - three projects).
- Call Topic SC5-13-2018-2019: International cooperation on sustainable urbanisation: NBS for restoration and rehabilitation of urban ecosystems (2019-2023 China – two projects; 2020-2024 CELAC – two projects).

[1] NBS are not limited to the projects in figure 4 as they are also present in other projects that are not NBS-focused, e.g. under Societal Challenge 5 (CLA-06 biodiversity & climate, and health & well-being); in Societal Challenge 2; in the EIT Climate-KIC; and in other pillars of H2020 (e.g. ERC or Marie-Curie grants).

- Call Topic LC-CLA-11-2020: Innovative NBS for carbon neutral cities and improved air quality (2021-tbc – three projects).

- Call Topic SC5-27-2020: Enhanced NBS for water security and ecological quality in cities (2021-tbc – two projects).

- Various other H2020 calls, including CSAs.

To accompany these actions, the EC has invested strategically in a range of platforms, databases and networks with the purpose of understanding NBS benefits and promoting knowledge exchange. This includes: the EKLIPSE impact evaluation framework (Raymond et al., 2017); the knowledge marketplace OPPLA (showcasing the latest thinking on ecosystem services, natural capital and NBS); the community-building actions of NetworkNature and now also NetworkNature; and databases and tools provided by specific projects and initiatives (such as NATURVATION's urban nature atlas). In addition, a series of city case studies were derived from FP7 project results, available in Oppla. These EC-funded resources are complemented by other online systems at the global level e.g. the Natural Hazards NBS tool supported by the World Bank.

2.3.4. Advancing the development, uptake and upscaling of innovative NBS

An important result of the EU's NBS research and innovation policy has been the wide range of case studies of implementation and best practices in diverse urban, peri-urban and rural contexts. The current phase of the EU's R&I policy agenda focuses on providing evidence of the cost-effectiveness of NBS, through Horizon 2020. It also entails coordination across European and other institutions to link up relevant initiatives (e.g. ENROUTE, European Environment Agency (EEA) and EU Urban Agenda Partnership on Sustainable Land Use and NBS). All EU-funded projects on NBS work together in task forces to achieve a greater critical mass of knowledge, to reduce duplication and to facilitate progress towards strategic, shared goals. As example, the task force on impact assessment is preparing a handbook with a set of common indicators to measure NBS effectiveness in tackling several societal challenges (see Annex 8). Specific Task Forces (TFs) are as follows:

- TF1. Knowledge and data management;
- TF2. Impact assessment (indicators);
- TF3. Governance and business models;
- TF4. Communication;
- TF6. Co-creation processes.

Individual H2020 NBS projects includes expected impacts tailored to the specific challenges that each addresses, including efforts to champion the adoption of NBS in urban areas (such as the NBS Cooperation Manifesto launched at the Mantova World Forum on Urban Forests) and to develop capacity-building programmes e.g. UrbanbyNature. Further activities to promote the uptake of NBS have included EU-level events such as the NBS conference of the Estonian Presidency of the Council of the European Union (held in Tallinn, 2017) and the H2020 clustering action "Transforming Cities, Enhancing Well-being: innovating with nature-based solutions" held in A Coruña, Spain in 2018.

2.3.5. Mainstreaming NBS within the international agenda

Particular measures taken to promote global mainstreaming of NBS include Sector Dialogues, and relevant H2020 calls with China and CELAC countries under the banner of 'Strengthening International Cooperation'. These actions intend to capitalise upon existing experiences and good practices in Europe and beyond, and place a firm emphasis on the potential contribution of NBS to achieving the Sustainable Development Goals (SDGs, see also Figure 3). They also include cooperation and synergies with the activities undertaken within the Covenant of Mayors initiative for Climate and Energy initiative. The EU-Brazil Sector Dialogue on NBS for Resilient Cities has delivered substantive results, including a report documenting 25 case studies from both sides of the Atlantic, and an edited book on NBS and water challenges (Herzog et al, forthcoming), both illustrating how working with nature can have a positive impact on people's lives.

NBS are becoming increasingly important in international agreements and policy frameworks. For instance, both the UN Framework Convention on Climate Change[2] and the Convention on Biological Diversity are increasingly recognising, debating and promoting the potential of NBS to help reach their more ambitious goals and targets over the next decade. IPCC scenarios involving limiting climate change to 1.5°C rely heavily on land-use change mitigation methods and decreasing sources and increasing sinks of greenhouse gasses (GHGs) through ecosystem stewardship; the potential contribution of NBS in this regard is significant in scope and substance across a range of policy areas as described in this report, particularly bearing in mind the required safeguarding of biodiversity as described in the above definition. NBS have been highlighted by IPBES as a cost-effective way of meeting the Sustainable Development Goals (see also Fig.4; further detail on NBS and biodiversity is provided in Section 4).

2.4. METHODOLOGY AND PROJECTS COVERED WITHIN THE ANALYSIS

The full list of projects reviewed is shown in Annex 1 (see also Figure 4), with Annex 2 describing the methods used in undertaking the analysis. Publicly available deliverables were analysed along with non-public deliverables, where access to these outputs was provided by the project consortia. The results of the analysis include invaluable information on the state of the art with NBS in EU-funded projects. Sections 3 to 11

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[2] See also the contribution from the European Commission to the NBS consultation for the 2019 UN Climate Summit.

present policy-relevant material drawn from detailed reports prepared by experts (shown in brackets), covering the following areas:

- Climate mitigation (Harriet Bulkeley).
- Biodiversity (Sandra Naumann and McKenna Davis).
- Water quality and waterbody conditions (Tom Wild).
- Flood mitigation and coastal resilience (Zoran Vojinovic).
- Microclimate regulation and air quality (Carlo Calfapietra).
- Sustainable communities (Harriet Bulkeley).
- Governance (Harriet Bulkeley).
- Market challenges and solutions (Kym Whiteoak).
- Research and innovation priorities in Horizon Europe and beyond (Tom Wild).

Available outputs were reviewed from the projects NATURE4CITIES and NATURVATION, which investigated new governance, business and financing models, and economic-impact assessment tools, from NAIAD, assessing the insurance value of ecosystem services and from PHUSICOS, RECONECT and OPERANDUM large-scale demonstrators of NBS for hydro-meteorological risk reduction. The analysis also covered the RIAs on strengthening international cooperation: REGREEN; CLEARING HOUSE; INTERLACE and CONEXUS (the first two include collaborations with China, the latter include partners in Latin American countries).

The valorisation review also entailed detailed analyses of results from the IA projects CONNECTING, GROWGREEN, UNALAB and URBAN GREENUP - implementing NBS for climate and water resilience, as well as those implementing NBS for urban regeneration: CLEVER CITIES; EDICITNET; PROGIREG and URBINAT. Information was also gathered via other networks and projects such as NetworkNature, BIODIVERSA and ESMERALDA. In addition the valorisation process involved reviewing FP7 and other H2020 projects, as well as key projects funded by LIFE+, COST and ERDF (Annex 1). Due to their early stage of development, some new projects awarded funding through very recent H2020 calls were beyond the scope of the current analysis, and are not considered in this report.

The EU's NBS research and innovation policy agenda has evolved rapidly from initial work to develop concepts and definitions, through exchanges of practices and case studies, into benchmarking and synthesis of evidence and now into consolidation of evidence on the cost-effectiveness of NBS. This report marks a particular point in this journey as the H2020 programme transitions into Horizon Europe and as the need to address climate change and biodiversity loss has reached crisis status. The valorisation project was undertaken within the context of the development of the European Green Deal and in particular, provisions on the role of restoring biodiversity to help meet climate targets.

Nature-based Solutions for climate mitigation

Harriet Bulkeley

3. NBS FOR CLIMATE CHANGE MITIGATION

3.1. INTRODUCTION: THE POTENTIAL OF NBS FOR MEETING CLIMATE GOALS

The European Union has set out an ambitious goal to become carbon neutral by 2050 and to adopt a target to reduce total greenhouse gas emissions excluding those from land use cover and land use change to at least 450% below 1990 levels by 2030. Achieving these goals will require not only transformation of our energy and transport systems, but measures across the economy as well as efforts to harness the potential of nature to contribute to both mitigating climate change and enhancing our resilience to its impacts.

As has been shown over the past three decades, making progress towards these goals will require a multilevel approach that involves all levels of government as well as networks and partnerships between state and non-state actors (Bulkeley & Betsill, 2013). Since its launch in 2008, the EU Covenant of Mayors has mobilised action at the local level, with now over 10,000 local signatories representing over 300M people committing to over 180,000 actions towards EU goals for climate mitigation. The success of the EU Green Deal will also depend on mobilising action across regional and local government, as well as the engagement of businesses, civil society and communities.

Within this context, the potential for NBS to play an important role in addressing climate mitigation is receiving increasing research, policy and public attention.In 2019, Science published a paper suggesting that planting trees, on a massive scale and sustained period of time, represented 'one of the most effective solutions at our disposal to mitigate climate change' (Bastin et al., 2019: 78). Although the potential and feasibility of such a strategy, and the scientific quality of the underlying research, has been hotly debated (e.g. Skidmore et al., 2019), it is increasingly clear that interventions that address how land is used are both an effective and necessary part of how society can respond to the climate mitigation challenge.

The IPCC have found that "all scenarios that limit climate change to 1.5°C rely heavily on land-use change mitigation methods, as well as decarbonizing the economy" and that "decreasing sources and increasing sinks of GHGs through terrestrial ecosystem stewardship and improvements in agriculture are widely cited as having the potential to provide around 30% of the CO_2 mitigation needed through to 2030 to keep warming to less than 2°C" (Seddon et al., 2020: 2).

In this context, NBS for climate mitigation are seen primarily as those measures that conserve, restore or enhance "forests, wetlands, grasslands and agricultural lands" in order to either reduce CO_2 emissions or remove CO_2 from the atmosphere through specific measures such as "reforestation, forest conservation and management, agroforestry, cropland nutrient management, conservation agriculture, coastal wetland restoration, and peatland conservation and restoration" (Belamy & Osaka, 2020: 98). In short it is the capacity of NBS to sustain or enhance carbon storage and carbon sequestration that has to date attracted most interest.

Yet NBS can also contribute to climate mitigation through reducing energy demand. By providing thermal comfort from the scale of the building to the neighbourhood, NBS can reduce demand for heating and cooling and in turn create energy savings. Alternatively, NBS can be used to create a conducive environment for active transport – walking and cycling routes that connect green spaces and create space dedicated for pedestrians and cyclists – in turn potentially contributing to reducing the use of cars and their associated emissions. It may also be the case that NBS can contribute to reducing the generation of embodied emissions in urban development and infrastructure provision – by using alternative materials to concrete and steel, which are both globally important sectors when it comes to the production of greenhouse gas emissions, building with NBS may support climate mitigation.

This section explores how NBS can contribute to climate mitigation through both storing and sequestering carbon and through reducing energy demand. It suggests that both offer significant potential within Europe and beyond for addressing the challenge of climate mitigation, but do so in very different ways. The potential for storing and sequestering carbon is largely to be found in rural areas and depends on interventions that take place in the agricultural and forestry sectors. In contrast, the potential for energy demand reduction is largely an urban issue, requiring interventions in urban development, infrastructure provision and the management of both public and private green space in cities. As well as taking place in different settings and involving different key actors, the trade-offs involved in NBS for climate change also vary. When it comes to those that seek to mitigate climate through carbon storage and sequestration, concerns centre on their potential impact on biodiversity. While those NBS that are designed to contribute to addressing thermal comfort in the city might increase natural habitat and species diversity, here potential trade-offs arise through their demand for water and how this might be managed in increasingly drought-prone urban areas.

The parts that follow consider in turn how NBS can contribute to climate mitigation and provide some examples drawn from research and innovation projects taking place in Europe. Overall, this section examines what works on the ground, as well as the challenges that have been faced and how these might be overcome. In conclusion, key lessons and areas where future research is needed are identified.

3.2. STORING AND SEQUESTERING CARBON THROUGH NBS

NBS that conserve or enhance carbon stocks have risen rapidly to prominence on the global agenda over the past few years. While the value of such interventions has long been recognised within the climate community, as successive IPCC reports and the development of the REDD+ instrument to enable the financing of land-use and forestry interventions has shown, the Paris Agreement and growing momentum behind the need to reach 'net zero' emissions have brought a new urgency to exploring their potential. Following the 2019 UN Climate Action Summit, which took NBS as a key theme, the NBS Contributions Platform and Compendium of Contributions on NBS have been developed under the auspices of the UN Environment Programme. If in the past a focus of such initiatives has been on how managing land use and land-use change should take place in the global South in order to mitigate climate change, NBS for climate mitigation are now seen to be applicable in all global regions.

In Europe, the evidence base reviewed for this report (see Annex 1) suggests that there is significant potential for using NBS for climate mitigation through storing and sequestering carbon (Table 1). This evidence points to two key arenas for action, the management of agricultural land and the conservation and management of forest ecosystems. There is also a growing evidence base concerning the potential for urban NBS to contribute to the storage and sequestration of carbon. In addition, there is an increased interest in the potential for 'blue carbon' especially in the form of the restoration of sea grasses and salt marshes, which is being supported by a range of initiatives across Europe. While there is strong initial evidence that such interventions can support climate mitigation (see for example), the evidence base is currently not sufficiently extensive to be included in this report.

CARBON STORAGE	CARBON SEQUESTRATION
The absolute quantity of carbon held within a reservoir at a specific time is referred to as a carbon 'stock'. This reservoir is a component of the climate system, other than the atmosphere, which has the capacity to store, accumulate or release carbon. Oceans, soils and forests are examples of reservoirs of carbon.	The process of increasing the carbon content of a carbon reservoir other than the atmosphere. Biological approaches to sequestration include direct removal of carbon dioxide from the atmosphere. Vegetation removes CO_2 from the atmosphere through photosynthesis.

Table 1. NBS for climate mitigation: carbon storage and carbon sequestration

3.2.1. Land management

A critical factor shaping the carbon storage potential is the nature and extent of soil erosion, which leads to a loss of topsoil, including soil organic carbon as well as the extent to which organic matter is added to soil over time. Good soil management is thought to provide an especially long-term NBS for climate mitigation, given that soils can effectively sequester carbon, keeping it away from the atmosphere.

At present, soil management in agricultural systems is not proving to be effective in this regard, with calculations suggesting that there is a significant loss of soil organic carbon across diverse geographical regions and agricultural production systems so that European soils in agricultural areas are likely to be net contributors to rather than sinks of atmospheric carbon (Lugato et al., 2016). Indeed, research by the PEGASUS project suggests that "around 86% of the European agricultural areas showed soil organic carbon losses from erosion" (Pérez-Soba et al., 2018: 44), with greater losses in more intensively managed systems (e.g. vineyards or permanent crops) than in those with lower levels of management intensity (e.g. citrus farming or horticulture) (Pérez-Soba et al., 2018: 46). While this research suggests that the loss of soil organic carbon varies within different agricultural systems, due to the specifics of topology and climate, it also points to the importance of land management practices in shaping the potential for carbon storage in European soils.

Evidence suggests that agro-forestry, land use systems where trees are grown in combination with agriculture, can offer potential as an NBS to improve land management, including the enhancement of soil organic carbon (Hernández-Morcillo et al., 2018). When based on agrobiodiversity, these systems can also contribute to tackling biodiversity decline (for more on agrobiodiversity see section 4). Whilst such agro-forestry systems are rather widespread across Europe, comprising approximately 20 million hectares, "the expansion of existing areas of agroforestry and the establishment of new agroforestry systems has remained limited" (Hernández-Morcillo et al., 2018: 50). Specific kinds of NBS identified that could enhance the use and development of agro-forestry for climate mitigation included adopting management practices for improving soil organic carbon, intercropping with leguminous plants, and the use of tree varieties adapted for different climate conditions (Hernández-Morcillo et al., 2018: 49).

Yet the uptake of such solutions remains limited, with key barriers identified as including the knowledge, skills, support and finance required to integrate trees into existing livestock or arable farming systems. Rather than lying in developing new solutions for managing agricultural land, much of the challenge that remains lies in (perceptions of) the socio-economic viability of such interventions, the traditional management systems within which they need to be implemented, and governance conditions which provide either limited incentives or send mixed messages about the value of these NBS within the agricultural sector. Furthermore, despite their higher overall productivity (Graves et al., 2007), the low profitability of such systems under the current regulatory and market conditions underlines the importance of developing "safe economic routes" or options for "the diversification of marketable products, and improvement of business opportunities through targeted marketing strategies" were seen to be critical in generating the wider uptake of these kinds of NBS (Hernández-Morcillo et al., 2018: 50).

BOX 1. DEVELOPING NBS TO SUPPORT LAND MANAGEMENT & LIVELIHOODS

The SOIL4WINE project has sought to address environmental challenges and the economic viability of this wine sector through the introduction of new soil management and agricultural practices. Pilot areas included in the project in Northern Italy were showing a significant decline in both the area under viticulture production, the productivity of vineyards, and their economic viability, with knock-on effects on the regional economy. Results indicate that improvements in soil management can yield important ecosystem service benefits, including water infiltration, reduced soil erosion, improving biodiversity and carbon sequestration, which are of significant value. Analysis suggested that the "potential total value of all ecosystem services provided by an appropriate management of the vineyard" supported by a new Decision Support Services "is equal at least to 20% of the value of total sales" from the vineyard. In order to capture this value for farmers, new 'payment for ecosystem services' tools and approaches may be needed that will not only encourage good environmental outcomes but help build the economic resilience and social cohesion of areas dependent on viticulture in the future.

In addition to managing agricultural land, the management of existing wetlands and peatlands is critical for carbon storage. Bonn et al. (2016) report that while peatlands cover <3% of the world's surface, they hold two times more carbon than the entire global forest biomass pool, and represent more than 30% of the total global soil carbon store. Holden (2005) stresses that the long-term ability of peatlands to absorb carbon dioxide is dependent on changing climate or management, which can alter peatland hydrological processes and pathways for water movement across and below the peat surface (driving carbon storage and flux). However, climate mitigation through NBS such as the creation and restoration of upstream wetlands is far from straightforward, not least because these habitats also emit other greenhouse gases such as methane (Green et al., 2018).

3.2.2. Forests and forest management

According to the IPCC, much of the "mitigation potential from terrestrial ecosystems comes from restoration and management of forests and from curbing deforestation", particularly in tropical areas due to the fast rates of tree growth and the lesser risk of adverse impact on the earth's albedo (Seddon et al., 2020: 4). The potential of such measures has been calculated by the IPCC to lie in the "range of 0.4–5.8 Gt CO_2 yr−1 from avoided deforestation and land degradation, as well as a carbon sequestration potential of 0.5–10.1 Gt CO_2 yr−1 in vegetation and soils from afforestation/reforestation" (Seddon et al., 2020: 4). Recent analysis suggests that restoring tree cover to 900 mha calculated to provide viable conditions for such interventions could 'draw down' some 200 Gt of carbon at full maturity, and that even if 10% of such an opportunity could be realised restoring forests offers a significant NBS for climate mitigation (Bastin et al., 2019). Yet concerns have also been raised that such potential relies on plantation forests, generating monocultures with little biodiversity value and where evidence that such systems can contribute to the long-term storage of carbon is still limited (Seddon et al., 2020).

BOX 2. FOREST MANAGEMENT FOR CARBON CREDITS

The CLIMARK project aims to contribute to 'climate change mitigation by increasing sink capacity and carbon stock protection in Mediterranean forests, and promoting multifunctional management with the creation of a climate credit market.' Through pilot actions across Catalonia the project will investigate how different forest management practices and agro-forestry techniques can support carbon storage and sequestration. A comprehensive evaluation of carbon mitigation through forestry management will then underpin the design of a Voluntary Climate Credit Market. This market will connect the producers of climate credits (forest owners with climate mitigation forests) and those looking to consume voluntary carbon credits to offset emissions from the businesses. It is due to be trialled in Catalonia and Veneto.

In the European context, evidence suggests that existing forests may have the capacity to sequester carbon of the equivalent of up to 13% of total EU greenhouse gas emissions from the burning of fossil fuels (Pérez-Soba et al., 2016: 24). While the rates of storage and sequestration in natural forest systems are largely a matter of their ecological composition and functioning, in managed forest systems this balance is driven by the economics of demand for forest products and the management practices through which they are produced (Pérez-Soba et al., 2018). As a result, research points to a trade-off between developing forestry systems for their non-market goods (carbon storage, biodiversity) and for commercial purposes of wood production (Pérez-Soba et al., 2018: 70-71). This suggests that there may be potential for developing NBS within managed forestry systems that can enhance the storage and sequestering of carbon, whilst also supporting the continued economic productivity of managed forests.

3.2.3. Urban nature

Despite their small scale, there has been a growing interest in the potential for NBS that focus on the conservation and restoration of urban forests and which support the planting of urban trees and other ecosystems for the storage and sequestration of carbon. As cities have come to mobilise action towards both climate mitigation and adaptation, and in the face of critiques concerning the politics and ethics of 'offsetting' emissions to distant others, local interventions to store and sequester carbon has become a matter of considerable interest at the municipal level.

BOX 3. INNER-CITY TREE PLANTING, BOLOGNA, ITALY

Funded under the LIFE programme between 2012 and 2013, the GAIA project, in Bologna, Italy, established a public-private partnership through the 'green areas inner-city agreement,' where private firms pledged to plant trees in the inner city. This allowed local enterprises to decrease their carbon footprint while also generating environmental and social benefits for the community. To date some 2,300 of the target 3,000 trees have been planted, and a toolkit was created to monitor the contribution to carbon sequestration and air pollution. The intention is to continue until the tree planting target is met.

Summary of cost and benefits:

Project budget:	€ 1 202 000
Number of trees planted:	2320
Cost of 1t CO_2 sequestrated (over 30 years)	€ 1 202 000 /2320 = € 518

*with one tree sequestrating 1 ton of CO_2 in 30 years

Source: https://naturvation.eu/atlas

Yet studies reveal that the potential for using NBS to store and sequester carbon at the local level remains very limited. In Barcelona, in line with other studies, research found that "direct net carbon sequestration…makes a very modest contribution to climate change mitigation relative to total city-based annual GHG emissions (0.47%)" (Baro et al., 2014: 475). Despite the limited overall contribution to climate mitigation identified in this research, its findings demonstrate that certain kinds of urban land-use – urban green spaces and low-density residential areas containing private gardens – are the most valuable for storing and sequestering carbon, suggesting that future urban NBS that are delivering other benefits in these domains could also be contributing to climate mitigation (Baro et al., 2014: 472).

Most studies to date have included relatively few urban domains in their analysis of the potential for storing and sequestering carbon – this is in part because the most frequently used evaluation tool available for urban assessment, the **i-tree Eco model** is intended to be used for evaluating the contribution of urban forests/individual trees, based on estimates of the carbon sequestered by above ground tree mass in North American trees (Elmqvist et al., 2015; Table 2).

TABLE 2: Estimated climate mitigation contribution from urban nature
Estimates of the contribution of urban forestry and urban trees to storing and sequestering carbon in cities using the I-tree model

CITY	ESTIMATED CONTRIBUTION TO MITIGATION	REFERENCE
Barcelona, Spain	Net annual carbon sequestration per hectare: 536 kg/ha/ year	Baro et al., 2014
Syracuse, USA	Net annual carbon sequestration per hectare: 540kg/ha/year	Nowak and Crane, 2002
Baltimore, USA	Net annual carbon sequestration per hectare: 520 kg/ha/year	Nowak and Crane, 2002
Averaged over 28 cities and 6 states in the United States	Average carbon storage density per unit tree cover: 7.69 kg C/m² and average gross carbon sequestration rate per unit tree cover: 0.28kg C/ m²/year	Nowak et al., 2013
Averaged over 5 European cities	Averaged net carbon sequestration 2.43 t/ha/year, carbon storage 20.85 t/ha;	Baro et al., 2015

Source: Elmqvist et al., 2015; Naturvation, 2019a.

More recent approaches have sought to develop more comprehensive analyses of the potential for storage and sequestration in the urban arena. The **InVEST** (Integrated Valuation of Environmental Services and Trade-offs) model, developed by the Natural Capital Project, based at Stanford University in the USA, uses maps of land use along with stocks in four carbon pools (i.e. above-ground biomass, below-ground biomass, soil and dead organic matter) to estimate the amount of carbon currently stored in a landscape or the amount of carbon sequestered over time. However, while this approach can be applied to the urban arena, it has yet to be specifically developed for this context.

The NBS Navigator, developed to support decision-makers in identifying the potential synergies and trade-offs for different kinds of NBS in contributing to sustainable development goals, has sought to extend the number of urban domains for which the storage and sequestration potential is understood. Of particular significance is their finding that urban blue areas can also contribute to climate mitigation (Table 3).

TABLE 3: Relative contribution of NBS in different urban domains for carbon storage

NATURE-BASED SOLUTION	SCORE	VALUE (average) (kg carbon/m²)
Parks and (semi) natural urban green areas	5	32.6
Urban green areas connected to grey infrastructure	4	28.9
Blue areas	5	36.1
External building greens	2	5.4
Allotments and community gardens	4	23.7
Green areas for water management	2	12.5

Source: Naturvation 2019a. NB The scoring is designed to provide an indicator of the relative contribution of NBS in each domain to the indicator (carbon storage), with five being a relatively very good contribution and 1 being a relatively very weak contribution.

3.3. ENERGY DEMAND REDUCTION

Despite efforts to address climate change, research suggests that society will experience a range of impacts from the changing climate over the next thirty years and into the second half of this century. One particularly acute challenge which has significant implications for our future energy demand is that of increased incidents of extreme heat. Research undertaken by the UCCRN for the C40 Cities Climate Leadership group suggests that some 970 cities with a population of over 100,000 people will be regularly exposed to a three-month average temperature of 35°C or above, with 45% of the world's urban population living in cities with these conditions an increase of 700% on today's figures (UCCRN, 2018).

While these impacts, and the risks they pose in terms of food and water shortages and health, will be felt most outside of Europe, this analysis shows that many southern European cities will be exposed to these extremes (Figure 5). In addition, it is expected that other cities across Europe will experience a higher number of extreme heat days, as witnessed in the Summer of 2019 across large parts of the region. Indeed, recent analysis suggests that in addition to the cities of Madrid, Rome and Athens that are commonly associated with extreme temperatures, "other cities, namely Valletta, Sofia, Wien, Zagreb, and Zurich should expect serious impacts in the future" (Smid et al., 2019: 399).

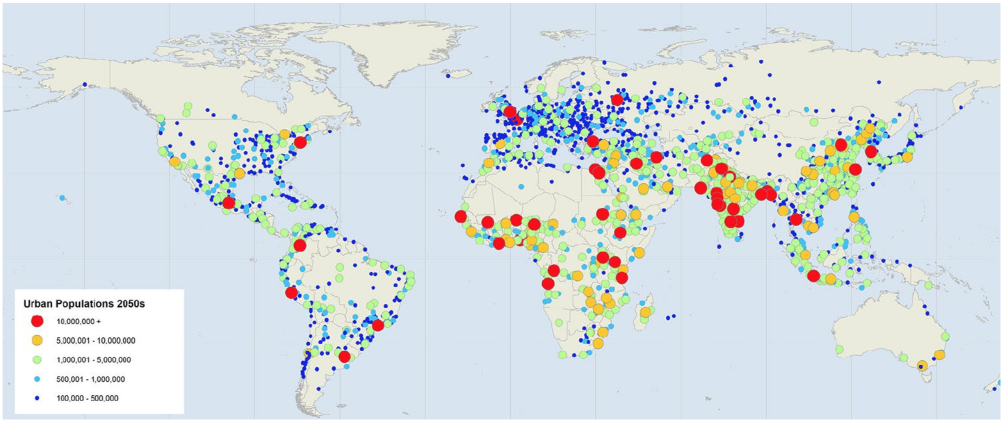


Figure 5: Urban Population Centres experiencing 3-month average 35 degrees in the 2050s.
Source: UCCRN, 2018: 13 © UCCRN.

The impacts of extreme heat will not only affect urban populations, but also their demand for energy. Cities are considered to contribute approximately 70% of all energy-related GHG emissions globally. A key source of increasing energy demand will be in the form of air-conditioning, as cities seek to manage extreme heat. The International Energy Agency estimates that 10% of all global electricity demand is used for cooling today, and that this figure is set to triple by 2050 (IEA, 2018a).

Of particular concern is that demand for cooling drives peak electricity demand. Meeting peak electricity demand often necessitates the building of new (fossil fuel) power stations just for this purpose or the use of standby generation capacity that is often very inefficient, for example the use of diesel generators. As a result, demand for electricity for air conditioning can disproportionately increase demand for fossil-fuel electricity power and contribute to increasing levels of GHG emissions.

Finding ways to cool the city are therefore going to be critical if we are to stay within the boundaries of a 1.5 or even 2 degree future world. NBS may have a critically important role to play, especially if they can be implemented before air conditioning becomes normalised across cities where it has yet to become 'locked in' to the built environment and everyday life. This section examines how NBS can be deployed at the city, neighbourhood or street level in order to address the urban heat island effect, before considering the potential for NBS integrated into the built environment in reducing demand for energy use in this sector.

BOX 4. FEELING THE HEAT?

One fifth of the energy used in buildings today – or 10% of the global total - is consumed by air conditioners and electric fans for cooling. By 2050, the International Energy Agency expects this figure to triple – creating an additional demand for electricity equivalent of all of that used by the US, the EU & Japan today. Left unchecked, the global total stock of air conditioners is estimated to grow to 5.6 billion, or 10 ACs sold every second for the next 30 years.

Source: IEA, 2018b

3.3.1. Cooling the city

The impacts of increasing global temperatures under climate change are exacerbated by what is known as the urban heat island effect, a phenomenon whereby urban areas experience both day and night time temperatures several degrees warmer than their surrounding areas. Of the four most commonly suggested approaches for managing this challenge - increasing the reflectivity of urban surfaces, changing urban morphology to enable greater ventilation at night, the use of vegetation and the use of water bodies - two require active intervention in the form of NBS (Aram et al., 2019; see also section 7). Indeed, such approaches are actively encouraged by the EU's Strategy for Strategy on Heating and Cooling (COM/2016/051) which suggests that "Nature-based solutions, such as well-designed street vegetation, green roofs and walls providing insulation and shade to buildings also reduce energy demand by limiting the need for heating and cooling."

BOX 5. GREEN CORRIDORS COOL THE CITY

In the GROW GREEN project Valencia is seeking to create a Green Corridor through the city by creating a series of green spaces or gardens that connect to existing green areas in the neighbourhood and provide a pedestrian route for citizens to use. In addition, green pergolas - structures built for shade and with planting to remove pollutants - as well as planning to maximise shade will be used to reduce heat stress. The intention is not only to create a more comfortable environment for citizens in the city, but also by taking account of natural ventilation and wind patterns to also cool the overall environment and reduce the energy demand of buildings in the neighbourhood.

There is now a significant body of literature that demonstrates that urban GI can have a significant impact on cooling the city not only directly within urban green spaces but also in their surrounding areas, known as the 'Park Cool Island' or 'Green Space Cool Island' effect (Aram et al., 2019). For example, an analysis of 47 studies comparing the cooling effects of green spaces in cities found that they "are on average 0.94°C cooler in the day than urban spaces, with stronger effects the larger the green space" (Seddon et al., 2019: 3).

In their analysis of the services provided by urban ecosystems, Elmqvist et al. (2015) report on a study conducted in Manchester, UK by Gill et al. (2007), which showed that "a 10% increase in tree canopy cover may result in a 3–4.8C decrease in ambient temperature." This is consistent with a recent comparative analysis of studies conducted globally also demonstrates that urban green spaces are consistently found to reduce temperatures in the city both during the day and, crucially, during the night. The cooling effect of urban green spaces was seen to increase not only with the size of such interventions, but also in relation to their density of their vegetation, species composition, shape, orientation and connectivity (Aram et al., 2019).

Urban NBS for cooling the city are not only to be found in green spaces, but also through interventions aimed to cool specific streets or open spaces in the city. In their analysis of the effect of tree planting in public streets and squares, NATURE4CITIES found that "trees can mitigate heat stress more effectively than low-hanging sun sails, installed right above the head of pedestrians. In the period of 9:00–16:00, the average Physiological Equivalent Temperature (PET) reduction by trees and low sun sails was 9.0 °C and 5.8 °C respectively" (Kántor et al., 2017). Their analysis suggests that given that shading in streets and squares can be provided by other buildings, the most important urban spaces for interventions of this kind are those which do not receive shade in this way, "sidewalks facing SE, S, and SW" where the use of NBS to provide shading from trees will be of particularly high importance (Kántor et al., 2017).

TABLE 4: Relative contribution of NBS in different urban domains for air cooling

NATURE-BASED SOLUTION	SCORE	MEAN VALUE (°C)
Parks and (semi)natural urban green areas	2	0.94 (95% CI of mean = 0.71–1.16)
Urban green areas connected to grey infrastructure	3	1.6 (0.43 – 3.06)
Blue areas	5	3.1 (1.6 – 5.2)
External building greens	2	1.1 (0.03 – 3.0)
Allotments and community gardens	No score	No values found
Green areas for water management	No score	No values found

Source: Naturvation, 2019c. NB The scoring is designed to provide an indicator of the relative contribution of NBS in each domain to the indicator (PET), with five being a relatively very strong contribution and 1 being a relatively very weak contribution.

Evaluating the relative effects of different urban NBS in terms of their potential for air cooling, NATURVATION finds that blue areas are an order of 2 – 3 times more effective than urban parks, with green areas connected to grey infrastructure (such as street trees) also producing an important cooling effect in the city (Table 4, above). However, when it comes to the capacity for NBS to have a direct effect on the thermal comfort of individuals, as measured by the PET indicator, urban parks as well as blue areas are the most effective intervention (Table 5, below).

TABLE 5: Relative contribution of NBS in different urban domains for reducing PET
Scores, physiologically equivalent temperature differences (°C) compared to parks

NATURE-BASED SOLUTION	SCORE	MEAN VALUE
Parks and (semi)natural urban green areas	4	0 (0 – 0)
Urban green areas connected to grey infrastructure	3	0.5 (-6 – 11)
Blue areas	5	-1.4 (-5.6 – 3)
External building greens	No score	No values found
Allotments and community gardens	(1)	Only a single value available (+3.5)
Green areas for water management	No score	No values found

Source: Naturvation, 2019c. NB The scoring is designed to provide an indicator of the relative contribution of NBS in each domain to the indicator (PET), with five being a relatively very strong contribution and 1 being a relatively very weak contribution.

To date, there are few studies that have explicitly considered ‘blue’ NBS for their capacity to provide climate mitigation benefits in this manner. A study by Kleerekopera and colleagues in the Netherlands suggests that “water can cool by evaporation, by absorbing heat when there is a large water mass – which functions as a heat buffer – or by transporting heat out of the area by moving, as in rivers” (Kleerekopera et al., 2012: 32; see also Hathway & Sharples, 2012). Designing NBS to effectively make use of these types of cooling function – e.g. through including forms of ‘fountain’ that are effective in creating evaporation, or by including sufficiently large water bodies to absorb heat – will be important as new ‘blue’ NBS are integrated into the urban domain. At the same time it should be noted that the potential of such ‘blue’ solutions to offer cooling services for the city and in turn to reduce energy demand may be compromised by water availability, given that may of the urban environments that will experience heat extremes and therefore could benefit from such solutions are also those which will experience a shortage of water.

Water availability is also a key factor shaping the capacity of urban green NBS to deliver cooling benefits, with research finding that where water shortages occur lower density canopies develop or the nature of vegetation is such that it offers a more limited cooling effect. In Milan, research found that this lead to urban greening being most effective in providing cooling during June, but less effective in July and August where restricted water availability led to a reduction in the effectiveness of these measures (Mariani et al., 2016). The management and maintenance of NBS is therefore likely to have a strong impact on their effectiveness in terms of cooling the city and reducing energy demand and hence contributing to climate mitigation.

3.3.2. Reducing energy demand in buildings

In addition to cooling the city and reducing the impact of the UHI, NBS can be used directly to reduce energy demand in the built environment. Within Europe, it is estimated that 36% of total greenhouse gas emissions are attributed to the building sector (Besir & Cuce, 2018) with most of these emissions stemming from the energy consumed for space heating and cooling. By regulating the thermal requirements of buildings, green roofs and green facades can provide an effective means through which to reduce energy demand. A recent overview of research conducted on the potential of these NBS to reduce energy demand in the built environment found that both green roofs and green facades provide highly effective insulation for buildings, with roofs reducing the heat penetration by up to 80% in some cases such that buildings with green roofs consume between 2-17% less energy than their counterparts, and that overall green surfaces can reduce the energy demand of buildings between 10-30% (Besir & Cuce, 2018: 936).

Evidence suggests that green roofs are most effective in reducing demand for cooling in the summer months, but can also contribute to providing thermal comfort in the winter so that demands for heating are also reduced. The effectiveness of such solutions is determined primarily by the thickness of the green roof installed and the vegetation used, or by the structure of the green facade in terms of its density and capacity for evapotranspiration, with thicker materials and more dense and varied planting not only contributing to greater energy savings but also providing new biodiverse habitats in the city (Besir & Cuce, 2018).

BOX 6. ROOF GARDENS REDUCE ENERGY AND ENHANCE BIODIVERSITY

Implemented in 2008, a green roof using native planting was established at the Hellenic Treasury (Oikostegi) in Athens with the aim of evaluating the contribution that such NBS could make towards reducing energy demand. Plant selections included indigenous Hellenic aromatic herbs and wild perennial flowers e.g. Hypericum and Phlomis and annuals such as poppies, grasses, and chamomile. The project led to a 50% reduction in the use of air conditioning on the floor directly below the installation. Energy savings totalling €5,630 per annum were recorded, translating into a 9% saving in air conditioning and a 4% saving in heating bills for the whole building. At the same time, the roof created a haven for birds and insects in the city.

Source: Urban Nature Atlas, NATURVATION

3.4. OPPORTUNITIES AND CHALLENGES: KNOWLEDGE, GOVERNANCE & INVESTMENT

That NBS offer a powerful tool for tackling the challenge of climate mitigation is now clearly established. Across Europe, projects and initiatives that are explicitly making this link have been able to effectively demonstrate the social, economic and environmental value of NBS. Given the prominence of the tackling climate change on policy and public agendas, showing how NBS can support a range of actors with their goals for climate change has provided a powerful means of attracting interest in and appreciation of the possibilities that NBS offer both for climate change and for sustainability more broadly.

In short, linking NBS to climate mitigation provides a clear means through which their value can be communicated and political support for their implementation generated. Equally, because carbon has an established monetary value, NBS that can demonstrate their capacity to store and sequester carbon are able to calculate the economic benefits they can generate, which in turn supports the development of viable business models and investment cases. Where NBS can lead to a direct reduction in energy consumption, creating a tangible and immediate reduction in expenditure, the cost-effectiveness of their implementation is also likely to increase. The explicit inclusion of climate mitigation goals in the design and development of NBS is therefore likely to enable the development of effective governance and business models that will support their mainstreaming. Yet realising these opportunities for mainstreaming and embedding NBS through climate mitigation is still fraught with challenges.

Turning first to those NBS with the potential for storing and sequestering carbon, a number of key challenges can be identified. The first relates to trade-offs between climate mitigation and other goals. Evidence suggests that within the forest sector, increased management and use of wood product can negatively impact on the potential for forests to store and sequester carbon. In the agricultural sector, trade-offs between intensive production and climate mitigation are also found. There is a clear need to develop transition pathways for affected sectors and regions that take account of concerns about the loss of livelihoods, employment, social cohesion and cultural ties that may arise through the widespread uptake of NBS.

At the same time, environmental organisations have expressed concerns that the use of NBS may be to the detriment of goals for nature and biodiversity should interventions take place that do not consider these outcomes as of equal significance to climate goals. The development and use of new standards for governing NBS may be one means through which to identify trade-offs involved, engage affected communities and stakeholders, and develop governance processes and forms of investment that are sensitive to the competing demands for future land use in Europe.

When it comes to the potential for NBS to deliver direct reductions in energy demand, a key challenge stems from the fact that because the framing of 'natural solutions' to climate change tends to focus on land and marine-based ecosystems the value of urban NBS for climate mitigation is often overlooked. While there is growing interest in the ways in which NBS can reduce heat stress within cities, the wider benefits in terms of reducing energy demand are not often calculated beyond the scale of the individual building.

Furthermore, issues of implementation are likely to be more complex in urban arenas due to the multiple actors who are involved in owning, managing and inhabiting the built environment. Classic 'landlord-tenant' issues, where those responsible for building or maintaining office or residential space do not benefit from reduced bills over time are likely to hinder the development of effective business models and financing for NBS that reduce energy demand. Likewise, implementing interventions at the street, neighbourhood or city scale encounters the challenge of how to gather the relevant actors and ensure that all of those who might benefit from a scheme are also involved in meeting (at least part of) the costs. As with other benefits, NBS that are designed for climate mitigation provide both public and private benefits which current governance arrangements and business models tend not to be able to capture and distribute effectively. Across all areas where there is potential for implementing NBS to address climate mitigation three further challenges are frequently encountered.

First, capacity to evaluate the climate mitigation benefits of NBS remains limited. Research has tended to focus on individual case studies or particular sorts of ecosystem, with knowledge of the storage, sequestration and energy demand reduction potential of diverse kinds of NBS being relatively weak. Furthermore, despite the development of new tools for evaluating NBS and their contributions for sustainability, many approaches lack sufficiently robust indicators or the potential to be applied to diverse NBS in different conditions. This may be because tools exist but there is limited knowledge or practical experience of their use amongst key stakeholders, or because appropriate evaluation techniques and models have not yet been developed.

Second, where implementation is taking place the value of climate mitigation alone is usually insufficient to build a business model or case for investment that can support the deployment or upscaling of specific NBS. Because NBS provide public as well as private benefits, some level of public finance is frequently required to enable and sustain such interventions over time. Equally, approaches are needed which enable the mitigation value of NBS for diverse beneficiaries to be combined with other benefits that they generate. Rather than seeking to establish business models that can make the economic case for NBS based on singular benefits or individual beneficiaries, achieving this outcome is likely to involving 'stacking' business models that can generate returns for a number of different actors and outcomes as well as finding diverse sources of finance that can be used to undertake initial investments.

Third, due to the multi-functional and multi-beneficiary character of NBS, they are often dependent on governance arrangements that bring diverse actors together. The implementation of NBS for climate mitigation is taking place through new governance arrangements – such as public-private partnerships or business-civil society collaborations – which require kinds of capacities for governing, including those which work to enable and facilitate collective action. There is limited evidence that regulatory or planning powers have been deployed by local or regional authorities in pursuit of climate mitigation outcomes. There is a strong emphasis on experimentation and project-based implementation as a means through which to realise the mitigation benefits of NBS. Scaling up such solutions may require that they become embedded in policy frameworks and planning regulations (e.g. building codes, land-use plans), but equally there is evidence that further work on how to develop just transitions through the use of NBS will be required if existing forms of economic and social practice are to be shifted towards the inclusion of NBS.

Overall, the implementation of NBS for climate mitigation has tended to be a rather technical endeavour, with a focus on the importance of generating new kinds of expertise, techniques, calculations and tools through which particular sets of stakeholders can be informed about the value of such approaches and educated as to how they should be adopted. There is less evidence to date that where NBS are being designed and deployed for climate mitigation sufficient weight has been placed on how to enrol key agents of change (e.g. architects, building managers, tenants associations, SMEs working in the farm and forest supply chains and so on) or those communities who might stand to benefit most from their deployment – for example, urban neighbourhoods that experience both heat stress and an inability to afford energy for cooling. Further engaging different kinds of public with the potential of NBS for addressing the climate emergency may provide a further opportunity for generating political will for their implementation.

3.5. POLICY RECOMMENDATIONS & KNOWLEDGE GAPS (CLIMATE MITIGATION)

In order for the potential of NBS for climate mitigation to be realised, a number of recommendations for policy and practice can be identified:

- Climate mitigation benefits of NBS are often too narrowly framed. There is promising evidence that NBS can support climate mitigation through reducing energy demand as well as through direct effects on carbon storage and sequestration. Public and private actors need to consider the full range of NBS that can contribute to the climate mitigation challenge.

- Support and guidance is required to enable private sector and civil society actors to implement NBS in the face of complex trade-offs and safe-guarding is required to ensure that climate mitigation is not achieved at the expense of biodiversity goals. Ensuring that there are trusted knowledge brokers who can support NBS development and implementation will be crucial for their widespread uptake.

- New approaches that bring multiple and novel 'agents of change' together in order to enable the development of pathways for mainstreaming NBS and ensuring 'just transitions' are required. Government agencies will be crucial for mobilising and enabling the capacity of other actors.

- There are opportunities to scale up NBS by embedding them in policy frameworks and planning regulations (e.g. building codes, land-use plans) and involving key agents of change such as architects, building managers, tenants associations, SMEs working in the farm and forest supply chains, and urban neighbourhoods.

- Climate mitigation benefits provide a basis for leveraging finance for NBS that tackle this challenge in addition to addressing multiple other sustainable development goals. There is a need for governance arrangements that bring actors who are willing to invest in climate facing NBS with those who are interested in other benefits that NBS provide in order to generate sufficient investment and robust business models.

With growing recognition of the importance of NBS for addressing climate change there are a number of key knowledge gaps that are critical to address in order to realise their potential:

- Our understanding of the carbon storage and sequestration potential of NBS tends to be dominated by particular ecosystems (forests) and derived from individual case-studies. Further research is required to establish how diverse NBS across multiple ecosystems and in rural and urban settings can store and sequester carbon.

- Our analysis of the potential impact of NBS for climate resilience and mitigation focuses on singular interventions. Further research is needed to develop both empirical knowledge and models/scenarios that can analyse the combined impact of multiple interventions at the landscape scale. There is also a need to build our understanding of the embodied carbon involved in the deployment of these initiatives and how this compares to other interventions aimed at ensuring sustainable development.

- There is a need to support research initiatives that calculate climate benefits at a broader multilevel scale, moving beyond individual buildings, case studies, and limited ecosystem types to understand the full diversity of NBS and involvement of diverse multilevel actors.

- There is a need to move beyond seeing the implementation challenge as primarily a ‘technical’ issue, to develop our understanding of the economic, social, political and cultural dimensions of designing and implementing NBS.

- There is limited understanding of the trade-offs involved in developing NBS for climate mitigation, both in relation to other environmental objectives (e.g. for biodiversity goals) and also in relation to other social and economic priorities. Further research on how NBS can be designed to contribute to the SDGs and the ways in which ‘just transitions’ can be enabled is needed.

Biodiversity and Nature-based Solutions

Sandra Naumann

4. BIODIVERSITY AND NBS

4.1. POLICY CONTEXT

Healthy and biodiverse ecosystems form the core of NBS and the key to success in using them to tackle societal, economic and environmental challenges. These underpinning conditions enable the delivery of critical ecosystem services and improved climate change resilience adapted to locally contextualised challenges (e.g. biodiversity loss, flooding, air pollution, and health and wellbeing). To ensure that ecosystems can deliver these benefits to their full potential, it is vital that biodiversity considerations are taken into account in the design and implementation of NBS and not sacrificed in preference for other priorities. Such a prioritisation is particularly important given the ongoing deterioration and decline of biodiversity in the EU, as shown by the 'State of nature in the EU' report (EEA, 2020).

The alarmingly low rate of EU species and habitats with a 'good conservation status' (namely 15 % and 27 %, respectively) has also been also recognised by the European Green Deal and the EU Biodiversity Strategy to 2030. As biodiversity is affected by diverse pressures and threats, there is a need to integrate biodiversity considerations in wider sectoral policies, including the Common Agricultural Policy (CAP). Key policies for biodiversity protection are presented in brief below.

The **European Green Deal** aims to make Europe the first climate-neutral continent by 2050. While NBS are only directly mentioned in the context of responses to climate change and healthy and resilient seas and oceans, biodiversity is recognised as a key area to contribute to climate neutrality. This is underlined by the Deal's ambition for all EU policies to contribute to the preservation and restoration of Europe's natural capital. The new EU Biodiversity Strategy to 2030 (see below) and 'Farm to Fork' Strategy for a fair, healthy and environmentally-friendly food system will be central in this regard. These and many other promising initiatives as part of the Green Deal have the potential to turn the biodiversity crisis around in Europe and encourage the use of NBS as a tool to do so. In order to achieve the desired impacts and be effective, however, clear objectives, measures, commitment, enforcement mechanisms, adequate financing and monitoring are needed.

The **EU Biodiversity Strategy to 2030** is an ambitious strategy that delivers on the EU and Member State commitments as parties to the UN Convention on Biological Diversity. The strategy aims to ensure that ecosystems are healthy, resilient to climate change, rich in biodiversity and deliver the range of services essential to the prosperity and well-being of citizens. Key topics addressed are protected areas, restoration of ecosystems, habitat and species status, urban green spaces, biodiversity to benefit climate and people, new biodiversity governance frameworks enabling transformative change, and supporting biodiversity through EU external policies. The targets address the main drivers of biodiversity loss and aim to reduce key pressures on nature and ecosystem services in the EU.

The Strategy further outlines the ambition to strengthen the biodiversity proofing framework for EU programmes and financing instruments. It seeks to unlock at least €20 billion a year for spending on nature via e.g. a dedicated natural-capital and circular-economy initiative under Invest EU, the EGD Investment Plan, the EU budget dedicated to climate action, and the mobilisation of further public and private funding at national and EU level. Nature-based solutions are highlighted as a key instrument for climate adaptation and mitigation and for greening cities. The ambition is high, but also necessary given that the previous EU Biodiversity Strategy to 2020 failed on many accounts (EFH, 2019; Langhout, 2019).

The **EU Birds and Habitats Directives** form the legislative cornerstone of European biodiversity and habitat protection, establishing an extensive network of nature protection areas called the Natura 2000 network. This Network covers 18% of the EU's terrestrial and 9% of its marine areas, and is considered a core element of Europe's GI. NBS can contribute to the connectivity of the network and support its management to better achieve conservation goals.

However, efforts to protect biodiversity are not limited to the Nature Directives and EU Biodiversity Strategy. A complex legislative framework of directives, policies, communications and programmes serve to address the range of pressures facing Europe's natural environment. Examples include the EU Regulation on Invasive Alien Species, EU Forest Strategy, EU Water Framework Directive, EU Marine Strategy Framework Directive, the Nature Action Plan, the EU Pollinators Initiative and the MAES (Mapping and Assessment of Ecosystems and their Services) process as well as the EU Green Infrastructure Strategy. This Strategy aims to ensure that the protection, restoration, creation and enhancement of GI in urban, peri-urban and rural areas become an integral part of spatial planning and territorial development to deliver essential services to people and nature.

According to Member State reports collected as part of the Nature Directives (Article 12 and 17), the most frequently reported pressures for habitats and species are from agricultural activities (e.g. abandonment of grasslands and intensification) (EEA, 2020). The **Common Agricultural Policy** is thus of critical importance to biodiversity protection, having the potential to reduce existing pressures (such as those stemming from direct payments) and make positive contributions through NBS, such as the promotion of organic farming or the establishment of multifunctional agro-ecological practices.

Land use and land use changes also play an important role in current policy debates at the EU and global levels, emphasising the need to **better link climate change and biodiversity policies**, including their respective targets and actions. In order to realise these ambitions, NBS are recognised for their potential to contribute to both climate change mitigation and adaptation, while contributing to biodiversity conservation, human wellbeing and other sectoral ambitions. More specifically, NBS can be strongly promoted and upscaled to protect, restore and create ecosystems with a high potential to sequester CO_2, such as wetlands, grasslands, peatlands, and biodiverse forests.

In addition to climate change, ecosystem restoration and biodiversity protection, discussions on the EU's and global biodiversity agendas is drawing attention to nature's contribution and benefits to people and the need to mainstream biodiversity into wider sectoral policies and reduce adverse effects, foster sustainability transition processes, maintain and increase ecosystem health and resilience, and deploy NBS at landscape level. Furthermore, the COVID-19 crisis in 2020 highlights the possibility that the destruction of ecosystems and harmful impacts on biodiversity may contribute to outbreaks of infectious diseases (Settele et al., 2020). Committed biodiversity conservation at global level is thus an important key to preventing new outbreaks.

4.2. LINKAGES BETWEEN NBS AND BIODIVERSITY PROTECTION

Tapping the full potential of NBS[3] to contribute to the EU Biodiversity Strategy to 2030 and the post-2020 global Biodiversity Framework targets requires a dedicated and measurable programme, accompanied by appropriate indicators for assessing the impact and progress.[4] NBS will play a central role in mainstreaming biodiversity across sectoral policies, as they benefit and are based on biodiversity, while also delivering multiple wider societal, environmental and economic benefits as described above and elsewhere in this report. On the other hand, NBS are systemic and will also increase the resilience of increasingly fragile nature reserves threatened by climate change. This multifunctional character also makes NBS a powerful tool to increase much-needed public and private sector investment in biodiversity conservation efforts, even if in many cases biodiversity is viewed as a co-benefit of the NBS rather than the primary objective. Ecosystem restoration will be a key component in delivering NBS for these aims. More specifically, the linkages between NBS and EU biodiversity policies can be explored in particular via the:

- Implementation of conservation measures by Member States to maintain, sustainably manage or restore natural habitats and wild fauna and flora in the EU territory and more specifically in the Natura 2000 network (as required by the Nature Directives).

[3] The NBS concept builds on and supports other closely related concepts, such as the ecosystem approach, ecosystem services, ecosystem-based adaptation/mitigation and green and blue infrastructure, which is illustrated by the findings from other sections of this project review. In this context, projects often refer to those similar concepts and not NBS exclusively.

[4] The NBS Task Force N°2 (TF2, see Introduction) coordinated by EASME and DG RTD works to develop common indicators to monitor and evaluate the impacts of NBS interventions within H2020 NBS projects and beyond, as a framework for more streamlined data collection and evaluation.

It is important to note that more traditional conservation measures, such as mowing or grazing grasslands, regular scrub clearance, management of hydrological regimes for wetland areas, would not qualify as NBS as they are more single-objective and aim to benefit species and habitats, while failing to adopt a more systemic approach and deliver multiple benefits.

- Creation of new and restoration of degraded ecosystems as part of the GI network to enhance the delivery of ecosystem services at landscape level, provide healthy habitats for species and improve the connectivity between areas in urban and rural areas throughout Europe.

These actions highlight the importance to protect and restore the existing ecosystems and biodiversity hotspots and to connect them with restored and re-established GI linking to the Natura 2000 Network. Such actions can ensure the coherence and connectivity of the Natura 2000 network and beyond, as a means to improve the conservation status of habitats and species. Relevant actions can include forest landscape restoration, floodplain management, river restoration, constructed wetlands or (re)introducing green corridors. A central condition for such interventions should be the maintenance and improvement of biodiversity, while also delivering benefits for other challenges such as climate change, flood protection, air quality and human health and well-being.

Figure 6. L:River restoration for flood protection in Grimma, Germany, NATURVATION © Sandra Naumann; R: Woluwe Park pond, part of Brussels green network, Belgium © Linda De Volder, Flickr (CC BY-NC-ND 2.0)

NBS are also essential to enable sustainable agriculture production systems. Nature-based farming practices are available that provide win-win scenarios, i.e. simultaneously addressing climate change mitigation and adaptation, biodiversity protection, soil and water management objectives. In the majority of cases, these also make long-term financial sense for farmers (improved resource efficiency and resilience to climate impacts), but there are short-term costs and risks that need to be overcome. Promoting NBS in rural areas requires a three-fold approach:

- broad application of agro-ecological agronomic practices - examples include cover/ catch crops and reducing bare fallow, retaining crop residues on the field, extending perennial phase of crop rotations, using perennial crops (also for alternative protein production), permaculture, using adapted crops, reduced tillage and zero tillage;

- promotion of agroforestry, woody landscape features or food forests, which can be part of a GI network and qualify as NBS given their multifunctionality; and

- enhancing agrobiodiversity for resilient farming systems, healthier nutrition and human well-being - this would encompass both nutritionally-rich biodiversity (cultivated and wild edible species) and 'functional agrobiodiversity'.[5]

In addition, urban areas have substantial potential to contribute to biodiversity protection by implementing biodiversity-rich NBS (urban allotments and gardens, green parks, pollinator sites, green corridors, restored wetlands, sustainable urban drainage systems or green roofs). These NBS interventions can bring additional- and more diverse- nature into cities, playing a critical role in improving human well-being and health, increasing social cohesion, raising knowledge and awareness, and re-connecting people with nature in highly populated and built areas.

To conclude, **biodiversity-driven NBS interventions** embrace nature protection and sustainable management measures, but go beyond these to deliver multiple benefits (e.g. for recreation, human health, climate change mitigation or food production) alongside contributions to species and habitat protection. By deploying systemic thinking, NBS should be used in ways which employ understanding of the structure and functioning of local ecosystems and wider landscapes as well as factors that can influence these systems over time, to address a broad scope of societal challenges. As such, biodiverse NBS are highly adaptable to effectively respond to changing local conditions and are often more cost and resource efficient than purely technological approaches (EC, 2015a).

4.3. THE EVIDENCE BASE: INSIGHTS FROM THE PROJECT REVIEW

4.3.1.The role of NBS to support biodiversity policy objectives

Several EU-funded projects have identified types of NBS that offer particularly high benefits for biodiversity (see Table 6). A few of the demonstration projects focus specifically on achieving and measuring these impacts on biodiversity. Relevant NBS include those aiming to improve ecological conditions, stop biodiversity loss, protect valuable ecosystems and landscape, enhance the delivery of a range of ecosystem services, improve functional and structural connectivity, create natural areas and/or benefit the Natura 2000 network in (peri-)urban and rural areas through locally adapted, resource-efficient and systemic interventions.

[5] Functional agrobiodiversity (FAB) refers to 'those elements of biodiversity on the scale of agricultural fields or landscapes, which provide ecosystem services that support sustainable agricultural production and can also deliver benefits to the regional and global environment and the public at large' (ELN-FAB, 2012).

TABLE 6. Types of NBS created and/or evaluated in research projects[6] with expected benefits for biodiversity

• Renaturing landfill sites, brownfields and river corridors • Restoration of catchments and coastal landscapes • Green roofs and walls • Cycle and pedestrian green route • Arboreal interventions (shade and cooling trees, planting and renewal urban trees) • Resting areas (green spaces projected for resting, relaxation, observing nature, social contact)	• Community-based urban farming and gardening • Connecting green and blue areas • Pollinator sites (verges and spaces, vertical/walls, roofs, modules) • Sustainable urban drainage system with plants providing habitats for insects and thereby birdlife, amphibians and/or native plants) • Urban rooftops combined with photovoltaic systems

Assessment frameworks designed to monitor the impacts of new or existing NBS typically contain indicators on biodiversity and green space management. Biodiversity indicators can include, for example: the relative proportion of natural areas, structural and functional connectivity, number of native bird species within urban GI, or a change in numbers of native species. A combination of spatial data and on-site surveys can be used to gather these biodiversity data (e.g. bees and butterflies) both within and in the proximity of a specific NBS. Indicators for green space management can focus on the distribution of public green space, accessibility of urban green areas, and ambient pollen concentration.

However, there are only a few examples of projects assessing the impact on biodiversity in greater detail. Exceptions include RECONECT and TURAS. Preliminary monitoring results from NBS implemented in RECONECT for example, show positive effects on biodiversity such as increased biodiversity, re-introduction of rare species and higher perceived naturalness (Penchev et al., 2019).

The TURAS project analysed the "Barking Riverside - brownfield landscaping" case study as an example of biodiversity-focused urban GI. The project demonstrated that the mosaic of habitats created within the landscaping have enhanced site biodiversity, recording 148 species of higher plants on just 0.5 ha of urban landscape; significantly greater floral diversity on brownfield landscaping areas than on surrounding soft landscaped areas were also identified (Connop et al., 2016). The authors concluded that such biodiverse GI can play a vital role in urban conservation efforts if incorporated at a landscape-scale (Connop et al., 2011; 2016).

6 These include RECONECT, PROGIREG, TURAS, URBAN GREENUP, URBAN ALLOTMENTS, GROWGREEN, PHUSICOS, UNALAB, NATURVATION and several LIFE projects (e.g. SCALLUVIA, GREEN4GREY).

Figure 7. Ephemeral wetland roofs and Bombardier Beetle (Brachinus sclopeta) at Barking Riverside
Image: Stuart Connop

Ecosystem restoration and management

Research projects and LIFE-funded demonstrators (i.e. GREEN4GREY, SCALLUVIA) conducted assessments, analyses and habitat enhancement activities to generate new knowledge on ecosystem restoration and connectivity. Significant progress has been made to map and assess the state of ecosystems and their services in their national territory in the EU and involving policy and stakeholder in this process (ESMERALDA, Maes, 2016, Maes et al., 2018a).

Moreover, projects such as MERCES and AQUACROSS have produced degraded habitat maps and identified ecosystem attributes (e.g. species composition, structural diversity and ecosystem functionality) and illustrated how these relate to the restoration potential in marine areas. This work provides a basis for the efficient restoration of marine and other habitats (Bekkby et al., 2017). The OPENNESS project developed a framework to identify priority areas for GI and its restoration across the EU Member States. Three scenarios (see Table 7 below) were developed to reflect the multifunctionality of GI, ecosystem service provisioning, and biodiversity conservation, and thus their simultaneous contribution to multiple policy objectives (Vallecillo et al., 2016: 8).

TABLE 7. Scenarios to identify priority areas for GI (OPENNESS)
1. **Nature for Nature (N4N)**: this scenario aims to identify multi-functional areas based solely on the supply of ecosystem services and the land use suitability for threatened and vulnerable species. It is based on the principle of GI aiming at 'protecting and enhancing nature and natural processes' 2. **Nature for People (N4P)**: this scenario aims to identify GI that would primarily enhance natural processes but also contribute to human well-being in a more direct way, so that a higher number of people may benefit from ecosystem services. Therefore areas closer to populated places are preferentially selected. 3. **Nature to Restore (N4R)**: this scenario prioritises multi-functional areas that are preferentially under poor ecosystem condition. The selected areas, therefore, would be closely related to socio-economic systems where drivers of change might compromise the multi-functionality in the long run.

A comparative assessment of these scenarios, building on spatial data, showed that GI could be efficiently established close to densely populated areas. Restoration costs in these areas are typically higher given the poor ecosystem condition resulting from degradation, but investment in those places was found the most cost-effective if human beneficiaries were accounted for in the assessment (Vallecillo et al., 2016: 11). This prioritisation framework has been taken up and further developed by JRC (Estreguil et al., 2019) to provide methodological guidance to support strategic policy and decision-making on GI from the local to the EU level.

Projects also investigated ecosystem-based management approaches and adaptive management to maintain ecosystems in a sustainable and integrated manner, and to measure the contributions to meeting EU biodiversity goals. As revealed by AQUACROSS (2016), ecosystem-based management can - by identifying the links between economic, social, and environmental goals - help identify trade-offs and pinpoint win-win synergies for biodiversity and human well-being. Such systemic and integrated approaches can be valuable to manage the inherently multi-sectoral, transboundary and spatial nature of biodiversity.

Other projects have also provided valuable forms of support for designing and implementing biodiverse NBS, such as: guidance to jointly assess biodiversity, ecosystem functions and ecosystem services in a qualitative or quantitative way (Domisch et al., 2017, AQUACROSS); tools to systematically integrate local knowledge and practices into formal environmental assessments and decision-making processes and support adaptive management approaches (Sharp et al., 2011; TESS, 2011); and insights on the correlation of different land use intensities and the status of biodiversity and ecosystem service delivery (Vallecillo et al., 2016).

Urban biodiversity

With a growing focus of H2020 NBS projects on cities, research and evidence on urban biodiversity is also increasing. An analysis of the 976 NBS cases in NATURVATION's Urban Nature Atlas revealed that the most frequently reported challenges addressed (circa 85% of the NBS) were the creation of green space and protection of biodiversity and habitats (Almassy et al., 2018). Yet only a third of NBS included in the Atlas have explicit biodiversity goals and actions. A more detailed analysis of these cases (Xie and Bulkeley, 2020) shows that many cities are already actively engaged in NBS with different types of biodiversity actions to conserve and restore nature (focusing more heavily on conservation) and mobilise people's ability to thrive with nature. Restoration was given higher priority (70% of projects) in urban rivers, streams, and estuaries, and lower priority (17 %) in community gardens. Moreover, circa 43% of NBS in large urban parks and forests have restoration goals and actions.

Figure 8. (a) Living Classrooms Thrive at Meadowwood Special Recreation Management Area. Image: Jennifer Stratton on Flickr (CC BY 2.0); (b) Pollinators at botanical garden Image: Lorna Winship.

Allotment gardens are studied in several projects as important urban green space features, providing e.g. food production, local climate regulation and air quality, aesthetic value of landscapes, pollination, and a location for socialising. Such gardens also host high plant species richness and diversity, including species of EU importance (Speak et al., 2015; Borysiak, 2016).

Research findings from the Urban Allotment Gardens project shows that deploying NBS or sustainable practices such as permaculture can boost biodiversity, but that local policy support is needed to promote urban biodiversity via education, social media or targeted planning processes. Accordingly, guidance and recommendations to foster and manage biodiversity-friendly urban gardens have been prepared for policy makers and gardeners (Jokinen et al., 2016).

TABLE 8. Fostering measures for urban biodiversity

To foster urban biodiversity and targeted GI planning and implementation, the ESMERALDA project identified the following needs (Balzan, 2017: 7):

1. Develop our understanding of biodiversity patterns in the city,
2. Soften the landscape to increase urban GI and biodiversity, and ecosystem service delivery, and
3. Support the notion that targeted GI planning contributes significantly to the creation of future liveable cities that support biodiversity and human well-being.

Agrobiodiversity

Different policies reflect the importance of ensuring the contribution of agriculture and forestry to maintaining and enhancing biodiversity by managing them in a sustainable way (e.g. Target 3 of the EU Biodiversity Strategy 2020, Aichi-Target 7, SDG 2). This is very important as the most frequently reported pressures for both habitats and species stem from agricultural activities, followed by urbanisation (EEA, 2020). The implementation of resilient agro-ecological practices as part of more efficient and sustainable food production systems can i) improve the ecological status of habitats, ii) increase biodiversity, and iii) help to strengthen capacity for climate change adaptation, not least through a progressive improvement of land and soil quality (CBD, 2019; Zwartkruis et al., 2015). There was little evidence on agrobiodiversity and the link to NBS (such as agro-ecological practices) in the reviewed research projects, but several LIFE projects made a significant contribution to increase biodiversity in (intensively used) farmland. This included restoring such farmland to valuable semi-natural habitats, agri-environmental measures to restore feeding and resting areas for specific bird species, biodiversity-friendly agricultural practices, or measures to reduce the impact of intensive agriculture on nearby nature areas. A few project examples which were implemented in Natura 2000 sites are presented in Table 9.

TABLE 9. LIFE projects increasing farmland biodiversity	
Dommeldal: Transboundary habitat restoration in the valley of the Dommel, NL/BE (link)	Transboundary restoration of heathland and wet forest biodiversity, establishing an ecological corridor and fostering extensive grazing. **Benefits:** increased quality of priority habitats (fens and alluvial forests), expanded habitats of breeding and other reed-inhabiting birds.
BioDiVine: Demonstrating functional biodiversity in viticulture landscapes, FR/ES/PT (link)	Implementing biodiversity-friendly practices on vineyards, i.e. use of inter-row ground cover, planting hedges, building or restoring traditional low walls, or allocating non-productive areas. **Benefits**: Enhanced quantity and quality of semi-natural features, improvement of arthropods, soil micro-organisms, birds, mammals, and plants.
AYBOTCON: Conservation of Botaurus stellaris and Aythya nyroca in SPA Medzibodrozie, SK (link)	Restoration and management of around 280 ha of water biotopes, creation of buffer zones (green zones) around wetlands on arable land to reduce agricultural pollution and eutrophication. **Benefits**: Increase of Bitterns and Ferruginous duck population and restored wetland ecosystems and functions.

Recent pilot-scale initiatives such as the Biodiversity for Food and Nutrition project (BFN) have demonstrated the value and additional benefits of underutilised nutrient-rich biodiversity by using innovative research partnerships and approaches to increase the knowledge, appreciation, awareness and utilisation of this diversity, encompassing both cultivated and wild edible species. These innovations and approaches are designed to meet the challenges of environmental sustainability, improved diet-related health and nutrition and betterment of livelihoods in the 2030 sustainable development context as well as contributing to biodiversity conservation (CBD, 2019:4).

Ecosystem resilience

There is little research on the extent to which biodiversity and related NBS contribute to healthy ecosystems and to building resilience. The TURAS project is one of the few projects, highlighting the potential of incorporating locally contextualised biodiversity-led urban GI design into the planning and policy spheres as a means to foster urban resilience (Collier, 2016). More commonly, projects instead focus on the conditions and factors to enhance urban resilience and increased adaptive capacity of cities without a specific focus on the role of biodiversity in this context (e.g. in OPENNESS and ENABLE).

4.3.2. Contribution of biodiverse NBS to climate and other policy objectives

NBS are increasingly recognised for their potential to contribute to a diversity of societal challenges, not least climate change mitigation and adaptation[7]. Carbon-rich ecosystems such as biodiverse forests, grasslands, peatlands and wetlands play a key role in sequestering carbon and supporting EU and global climate goals. These and other natural habitats across the EU are largely assessed by Member States as being in bad condition and/or needing to be restored or managed more sustainably.

The Stockholm Environment Institute estimated that on a global scale, extensive ecosystems restoration could provide 220-330 Gt of carbon dioxide removal (Kartha & Dooley, 2016). The importance of biodiversity and ecosystem restoration to achieve climate targets is not only emphasised in the new EU Biodiversity Strategy to 2030, but is also acknowledged by some European climate plans, demonstrating the benefits of such actions. Examples include seagrass meadow restoration in Portugal or the advice from the UK Natural Capital Committee[7] to prioritise NBS interventions, such as maintaining and increasing tree cover, peatland restoration or improving wildlife and biodiversity for 2050 climate neutrality.

While the contributions to climate objectives were explored across several projects, the explicit consideration of linkages and causalities with biodiversity in this context is limited. Positive relationships between biodiversity and ecosystem service (ES) delivery are widely implied and assumed within both the scientific and policy literatures, but empirical evidence is limited supporting these relationships (Filazzola et al., 2019, Schwarz et al., 2017).

The majority of reviewed projects instead consider biodiversity as one of several (co-) benefits of NBS and assume that implementing NBS will automatically improve both biodiversity and the delivery of ES, thereby contributing to diverse sectoral policy objectives. The role of particular species and specific functional traits are understudied. Schwarz et al. (2017) suggest that as urban planners are increasingly considering ecosystem service delivery in their decision-making processes, researchers need to address these substantial knowledge gaps to allow for the adequate accounting of potential trade-offs and synergies between biodiversity conservation and the promotion of ecosystem services. ENABLE was one of few projects to explicitly consider biodiversity as a factor in the delivery of ES from NBS. Within this project, Naumann et al. (2018) conducted a literature review which highlighted that only limited studies have explored

[7] More information on these topics can be found in sections 3, 5, 6, 7 and 8 in this report.
[8] Natural Capital Committee (2020) Advice on using nature based interventions to reach net zero greenhouse gas emissions by 2050.

the linkages between biodiversity attributes (species abundance, species diversity, and community habitat structure and species richness) and the delivery of cultural ecosystem services (e.g. landscape aesthetics and recreation). These are often linked only to taxonomic biodiversity metrics (species richness and diversity) rather than functional biodiversity metrics (e.g. habitat structure). URBES also produced a factsheet on biodiversity and human physical and psychological health and well-being (URBES, 2012), but this guidance only refers to 'trees' and 'nature' more broadly when outlining sectoral contributions.

TABLE 10. Measuring the contribution and value of biodiverse NBS

While several projects aimed to increase the evidence surrounding NBS contributions to climate and other objectives, the explicit consideration of biodiversity's contributions is limited. The following tools try to address this gap:

- NAIAD's Co$tingNature tool links biodiversity and climate change; by analysing biophysical co-benefits of natural capital, it indicates the overall conservation priority of areas that provide flood storage services, but which are not already protected; the tool can be used as a basis for targeting NBS at the EU level.
- TreeCheck App quantifies the contribution of specific types of plants to city climates, amongst other functions.

Tapping the full potential of biodiverse NBS to contribute to diverse sectoral targets necessitates a mainstreaming into existing policy frameworks outside of the green/environmental niche, rather than being treated as an isolated programme. In NATURVATION, Davis et al. (2018) reviewed and assessed the current type and degree of EU policy support for NBS, finding that significant room remains for increasing cross-sectoral integration of NBS and for considering biodiversity therein. Breaking silos remains a key challenge in this regard as well as increasing the knowledge and evidence base as a means to foster wider support and awareness of biodiverse NBS as a multifunctional approach to address societal challenges.

Accordingly, the need to increase awareness about these benefits is also critical to increasing the implementation and impact of biodiverse NBS (URBANGAIA, undated). Increasing recognition of the potential returns on investments in wetlands, urban forests and parks, green walls and roofs, and green corridors will in turn help promote and prioritise urban green space development and ecological restoration (URBES, 2014), as well as other biodiversity-friendly solutions e.g. composting, bee friendly cities, eco-friendly food production, eco-friendly gardening and lifestyles, nature conservation and management and nature education (Berry, 2018).

4.3.3. Consideration of nature-people interactions

NBS are associated with a range of benefits alongside biodiversity protection which are generated from the delivery of ecosystem services. These include, for example, climate adaptation and improved attractiveness for investors (Gill et al., 2007, Kabisch et al., 2016b; Wild et al., 2017). However, societal benefits arising from the delivery of cultural ecosystem services, such as reducing mental stress or fostering a sense of community, have been historically far less prevalent in NBS discourse. These considerations have been addressed by fewer research projects.

Biocultural diversity as a novel concept to assess the interrelatedness between people and their natural environment was studied in depth by GREEN SURGE as a response to challenges such as the loss of biodiversity and degradation of ecosystems in urban areas, and the loss of people's interaction with nature. This concept takes local values and the practices of different cultural groups relating to biodiversity as a starting point for creating solutions which support a sustainable coexistence between people and nature. Such knowledge is important to facilitate nature conservation and stewardship in cities and other populated areas (Elands et al., 2019). The ENABLE project, for example, adopted a wider perspective than the traditional ecosystem services approach to explore a diversity of cultural ecosystem services provided by urban ecosystems and biodiversity. These take into account relational values describing the human-environment relationship and further benefits, such as place attachment, identity, social belonging (Naumann et al., 2018).

Figure 9. Community garden in Bogotá and urban garden in London @Ewa Iwaszuk
Urban gardens to support environmental education. Image: Shutterstock

The concept 'Nature's Contributions to People' (NCP), driven by IPBES (2017), builds on the ecosystem services concept to encompass 'contributions, both positive and negative, of living nature (diversity of organisms, ecosystems, and their associated ecological and evolutionary processes) to people's quality of life. Literature on NCP emphasises the concept's ability to capture a range of worldviews, knowledge systems, and stakeholders (Kadykalo et al., 2019). In order to realise the potential of nature's contribution to people but also peoples' impact on nature, BIOMOT emphasises that a shift is needed in biodiversity policies to close the gap between intended and real policy actions. To this end, the project has designed a theory of committed action for nature to help society to act more effectively (BIOMOT, 2015). This framework involves building objectives, policies, programs and practices expressing the eudemonic values of nature (i.e. values of connectedness with nature that create meaningfulness in the lives of people, communities and nations). Most saliently, committed action for nature is fostered by people feeling connected with nature as part of a meaningful life.

4.3.4. Collaborative approaches for biodiverse NBS

The importance of stakeholders as knowledge-providers and contributors and thus the need to support wider participation in NBS-related activities is highlighted by numerous projects and supported with the development of e.g. co-creation guidelines (see e.g. CLEVER CITIES online co-creation guidance tool, which can be applied across different themes). Rarer, however is research focusing specifically on engagement with biodiversity and the added value that can be achieved through increased participation in biodiversity conservation or monitoring ambitions.

Projects working in this area focus largely on how to foster collaboration and involve stakeholders in inclusive planning and decision-making processes in order to take user needs, preferences and requirements into account. Such 'co-creation' processes enable the development of functional, effective and accepted interventions responding to local needs and also foster knowledge exchange, align stakeholder expectations and help build trust (see Table 11 for more examples).

TABLE 11. Evidence & tools for co-monitoring, mapping & data sharing

Several projects highlight the need for the co-production of knowledge on urban biodiversity and ecosystem services using transdisciplinary approaches:

- 'Ecology for the city': transdisciplinary paradigm to co-produce knowledge about urban ecosystems and their services and identify solutions for improved adaptation and urban resilience (ESMERALDA, Balzan, 2017)
- Use of training and mapping workshops for policy-makers and scientists to collaborate to deliver products based on reliable data and scientific expertise and enhance uptake of scientific outcomes in policy (Maes, 2016)
- Collaboration and co-creation of knowledge across multiple scales and sectors with city officials to introduce a systemic understanding of NBS (ENROUTE; OPENNESS; BIODIVERCITIES[9])

Tools developed to foster participatory biodiversity monitoring include:

- Tree Check app: engages the public in urban greenery care in a fun way, by offering the opportunity to help cool down cities by measuring tree cooling and monitoring their condition.
- MapNat app (URBANGAIA): enables mapping of the use of nature's services in locations where they are being used, providing access to other users' records; citizens can map or search for e.g. bird watching spots and report environmental issues such as bad water quality, pests, or plants causing allergies or hay fever.

PEGASUS case study research has shown how careful investment in more socially ambitious processes can generate long-term gains with important legacy impacts, fostering resilience among communities of shared interest to manage future challenges and uncertainties (PEGASUS, 2016). In order to do so, however, requires tailored approaches to (1) measure preferences for biodiversity and NBS, (2) take preferences into account in planning processes and (3) maintain ongoing engagement (where desired) throughout the NBS lifespan (Naumann et al., 2018).

The AQUACROSS project highlights that in order for ecosystem-based management (EBM) to be operational and benefit biodiversity, a level of common understanding

[9] BiodiverCities is funded by a grant of the European Parliament and implemented by the Joint Research Centre and DG Environment. It aims to to deliver a roadmap to enhance the biodiversity and green infrastructure in European cities by 2030.

and consensus is needed between scientists, policy-makers and stakeholders on the status of aquatic ecosystems and means to improve this. AQUACROSS supports the institutional processes (including decision-making) by conveying scientific knowledge and integrating stakeholders' perceptions and information to help establish the problem (through an assessment of the baseline scenario) and the design of comprehensive societal responses involving EBM management and policy scenarios (Piet et al., 2017). PHUSICOS underlines this finding, citing NBS co-design and innovative participatory processes to be a key governance enabler for successful implementation and long-term acceptance and impact.

4.3.5. Role of NBS to support sustainable transition processes

The topics of sustainable transition and transformation have been addressed by certain research projects from different perspectives, but the link to NBS and particularly biodiversity is not always elaborated.

Transformation of the biodiversity agenda

Developing and implementing integrative and holistic management approaches is a prerequisite for transition processes towards a more sustainable society. In this respect, different approaches for ecosystem restoration have been studied and tested by different research projects and are presented in Table 12 below.

TABLE 12. Integrative & holistic management approaches for restoration
Ecosystem-based management is an adaptive and sustainable ecosystem management approach considering ecological integrity, biodiversity, resilience and ecosystem services to enable the delivery of multiple benefits for human well-being and wider societal and policy goals (AQUACROSS, 2016).
Assessment frameworks should also consider physical processes and temporal and spatial aspects going beyond river restoration project boundaries and project life spans. In addition, well-defined quantitative success criteria, the application of existing planning and management tools and the adoption of a synergistic approach with other resource users are key (REFORM, Kampa & Buijse, 2015).
An **integrated valuation framework**, which takes account for the plural values of biodiversity and ecosystems should be used to ensure that social-cultural values are adequately considered in ecosystem management and restoration. A range of novel and innovative methods have become available to assess those values (ESMERALDA, Maes et al., 2018b).

Several projects emphasised the potential of policy to foster transition, through improved implementation of existing (EU) legislation, increased mainstreaming of biodiversity across policies, better adaptation of policies to local needs, and an 'uncoupling' of growth and resource use (Rouillard et al., 2017). In addition, polices should be designed to: support empowerment and innovation (e.g. focus on outcomes and results; encourage engagement in management); focus on capacity building, facilitation and multi-actor engagement; encourage more cooperation and collective approaches; and foster local governance (Maréchal et al., 2018).

The PATHWAYS project examined selected niche-innovations that combine land uses functions (e.g. agro-food production, nature management, water management) and collaborate with other actors or participate in different actions simultaneously (e.g. protecting against floods and creating nature). Pathways aimed at achieving more efficient land use and were assessed regarding their impact on biodiversity (Zwartkruis et al., 2015, see Table 13 below).

TABLE 13. Niche innovation and pathways analysed in PATHWAYS

1. Biodiversity in cities (urban farming) 2. Business and biodiversity 3. Local renewable energy production (Renewable energy production in agricultural systems (e.g. biogas, using by-products for energy production) solar/wind farms) 4. Resilient landscapes for ecological protection (Room for the river) 5. High nature value farmlands (Agricultural nature conservation: Agri-environmental schemes) 6. Natural heritage landscape (Tourism/ recreation in nature areas)	**Pathway A**: • Technologies and need for more societal acceptance moving from intensive to extensive land use due to increase productivity and rewildering (2015-2030) • From CAP to innovation policy (2030-2050) **Pathway B**: Changing consumption, perception and moving towards ecological intensification (2015-2030) – Broader regime transformation
Results show that both pathways imply relatively challenging transitions at many levels (e.g. societal, economic, technological). Total levels of biodiversity will increase in all scenarios of land use; higher values of biodiversity can be expected for Pathway B, as agricultural abandonment leads to an increase in natural habitat.	

Both pathways were found to require substantial reorientations of current trajectories (including policy support), but changes are only occurring slowly. The niche innovations that are likely to be able to break through in the short term are business and biodiversity. This reflects the need for alternative ways to finance nature and for an increased awareness amongst businesses of sustainability issues and the importance of biodiversity. Overall, the project concluded that transitions can be enabled if relevant actors change their commitments, strategies, investments and behaviours (Zwartkruis et al., 2016).

Figure 10. Sustainable farming landscape © Christian Heitz on Pexels

Necessary conditions for fostering transitions towards sustainability through NBS

The ARTS project highlights that engaging in NBS is a powerful way for transition initiatives and governments to address environmental challenges and bring about transformative societal change. This highlights the importance of local actors who can spark social innovation and accelerate sustainability transitions by bringing together governments, citizens and nature in the design and implementation of NBS (ARTS, 2016).

Focusing in particular on the contribution of NBS to sustainability transition processes, the following three findings are crucial: (1) collaboration is critical for change; (2) government bodies need cross-cutting interfaces and agile structures; and (3) change requires long-term investment. Such transitions require the use of new models of participation and collaboration across sectors and scales, new models for progressive social interaction, and paradigm shifts illustrating the potential of NBS by as a powerful tool to promote social and natural regeneration, re-connection, and collective-value creation (ARTS, 2016).

4.3.6. NBS governance to deliver biodiversity benefits

While numerous projects outlined potential governance models for NBS and key enablers for successful NBS planning, implementation, monitoring and maintenance, the large majority of findings do not draw explicit links to biodiversity. The findings are thus equally applicable to NBS for climate mitigation or adaptation, human well-being or biodiversity conservation, and even for sustainable approaches in general. Nevertheless, key findings in this area are summarised below (Table 14).

TABLE 14. Key governance enablers of successful NBS

- Fit-for-purpose polycentric governance, i.e. novel arrangements in the public administration involving multiple institutional scales and/or actors
- Financial incentives for community-based implementation and monitoring of NBS
- Integrated planning approaches
- Binding regulatory mechanisms, such as standards on green space availability
- Quantified, measurable targets relating to NBS deployment
- Political commitment at the national and city levels
- Targeted investments and financing (not least for providing advice, facilitation, cooperation, and capacity building to strengthen institutional capacities, knowledge and expertise)
- Collaborative planning and decision-making approaches, integrating a diversity of stakeholders
- Environmental advocacy coalition groups, along with individual champions to advocate for NBS
- Building of sufficient social capital and trust between actors

Regarding biodiversity specifically, the TURAS project (Collier, 2016) looked at the rehabilitation of damaged urban ecosystem services to boost urban biodiversity. They found that the creation of visions, feasible strategies, spatial scenarios and guidance tools to enable adaptive governance, collaborative decision-making, and behavioural change for more resilience, are central to achieving desired impact. The project also outlines the value of incorporating locally contextualised biodiversity-led urban GI design into the planning and policy spheres in order to ensure the functioning and resilience of the city and provide the adaptability to respond to locally contextualised challenges (e.g. flooding, air pollution, biodiversity loss).

GREEN SURGE also highlighted the value of considering biodiversity in urban GI planning and governance, particularly as relates to user preferences and the delivery of specific benefits. The project accordingly takes biodiversity and the biophysical structures of urban GI into account as well as user group diversity, and neighbourhood cultural and economic characteristics during the planning process. This application in the context of Western urban societies presents an innovative and novel approach and requires further operationalisation in urban GI planning and governance (Vierikko et al., 2015; 2017).

The need to account for local considerations is underlined by AQUACROSS (Piet et al., 2017), emphasising the identification, screening, and design of social and institutional conditions to enhance the governance in ecosystem-based management and contributions to achieving societal goals relating to biodiversity. Kenward et al. (2011) from the TESS project also confirm the benefits of adaptive management and add the importance of the role of leadership for the provision of ES. The project provides evidence from empirically justified governance strategies that are capable of improving the management of human-altered environments, with benefits for both biodiversity and people.

BESAFE (2015) looked to improve biodiversity policy making and governance at various scales. The project found that a top-down policy framework setting goals for the protection of particular sites and species is important, but that an integrated approach seeking to mainstream biodiversity concerns across all policy sectors and including biodiversity outside protected areas is what is really needed. This requires the cooperation and active engagement of all relevant stakeholders and investments by authorities to initiate, facilitate, monitor, guide and encourage collaborative decision-making processes and actively support an adaptive management approach wherever possible. This was also underlined by PHUSICOS, which draws attention to the value of polycentric governance as an enabler for successful NBS.

BOX 7. Isar River Basin case study: polycentric governance in action

Within the PHUSICOS project (2019), the Isar-Plan case study (Munich, Germany) successfully deployed a polycentric governance approach to restore an 8 km long river section as a NBS to increase flood protection, recreational potential and improve ecological quality. This required the regional and municipal water authorities to collaborate to advocate a far broader vision for the Isar than their customary focus on grey infrastructure for flood protection and was very time-intense, taking 13 years.

This collaboration was initiated by ecologically committed staff members who formed a multi-scale and cross-sectoral work group, which broke down the silos of water and urban planning and was unprecedented for projects of this magnitude and involved multiple institutional scales and sectors to include not only flood and landslide protection, but also nature conservation, urban planning, water quality, waste management, tourism, recreation, and many more administrative responsibilities.

Figure 10. Isar seen from the Wittelsbacher. Bridge Image: Rufus46, Wikimedia Commons (CC BY-SA 3.0)

4.4. MARKET UPTAKE, BUSINESS MODELS & FINANCING (BIODIVERSITY & NBS)

A growing body of evidence is emerging on the cost, benefits and cost-effectiveness of NBS, but data are largely lacking on quantified biodiversity impacts. This field has not yet reached its potential in fostering increased market uptake and replacing or more widely complementing grey infrastructure solutions.

Costs for implementing biodiversity-supporting NBS, such as restoration activities, vary a lot depending on the status of the (degraded) area to be restored and its location. OPENNESS found that restoration costs for interventions close to densely populated areas are typically higher than in more sparse areas given poor ecosystem conditions due to degradation. These costs can be compensated if beneficiaries (i.e. people) were accounted for in the assessment (Vallecillo et al., 2016).

Costs also vary with the type of ecosystem and their dynamics. Ecological processes in marine ecosystems and in particular open seas ecosystems, for example, are generally slower than land ecosystems. This means that restoration activities require a mechanism for long-term commitment that exceeds typical business and political cycles (Morato et al., 2018).

While costs per hectare for restoration activities in marine ecosystems are reported as being high around the world (i.e. reported between 80,000 and 1.6 million USD for such ecosystems as coral reefs, seagrass meadows, mangrove forests, salt marshes and oyster reefs (Bayraktarov et al., 2016)), the MERCES project showed that the return on investment from the delivery of ecosystem services far outweigh these costs (Morato et al., 2018). Such services include improved water quality, enhanced fisheries, carbon sequestration and flood protection.

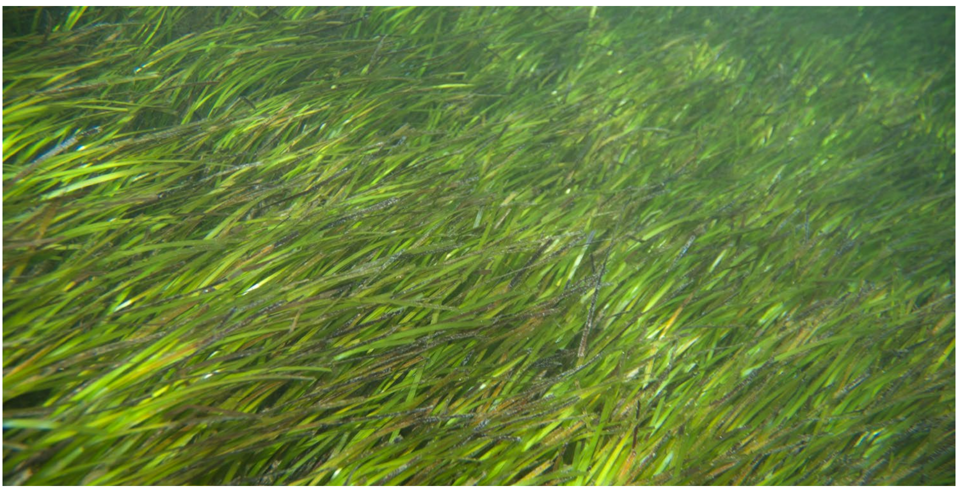


Figure 11. Seagrass Halodule uninervis © Paul Asman and Jill Lenoble on Wikimedia Commons

In order to achieve a positive cost-effectiveness ratio, long-term perspectives and the full range of ecosystem services and benefits produced by NBS need to be taken into account and monitored.

However, biodiversity assessments and monitoring frameworks are rarely established as part of NBS design and implementation in urban areas (Almassy et al., 2018). There is also a lack of accepted universal methodology, which can be applied to place monetary values across these multiple benefits and to collect data to measure the impact at the NBS-scale (i.e. not at a city scale, but rather at the intervention scale itself). The case studies in Table 15 below illustrate the range of quantitative and qualitative benefits that can be provided by NBS, which were designed with the primary aim to benefit biodiversity.

TABLE 10. Quantitative and qualitative benefits of biodiverse NBS

NBS INTERVENTION	BIODIVERSITY AND OTHER BENEFITS	SOURCE
Connecting two parks with a green corridor, greening a former grey area in Athens, Greece	• Increase of 2.43 m²/ habitant in green area access • 30 % rising biodiversity in the area • 27,9 t/y CO_2 captured • 85 % reduction of dust particles	Almassy et al. (2018); NATURVATION
Constructed wetlands as a multipurpose GI in Gorla Maggiore, Italy	• Maintain and improve biodiversity • Mitigate water pollution, potentially increa¬sing the ecological status of the Olona River • Contribute to the residents' livelihood via recreational and educational services	OPENNESS 2018
Creation of an edible forest increase the biodiversity in an peri-urban area in Alcalá de Henares, Spain	• Increase biodiversity, quality and quantity of green and blue infrastructures and ecological connectivity • Restoring ecosystems & functions • Carbon sequestration and storage • increase social inclusion	OPPLA case study, city council project

NBS INTERVENTION	BIODIVERSITY AND OTHER BENEFITS	SOURCE
Soil wild bees habitats - La Citadelle Park, Lille, France	• Restoring ecosystems & functions • Increase biodiversity • Increased cultural richness and biodiversity	OPPLA case study; Nature4Cities
Ecological infrastructure in Port of Antwerp, Belgium	• Create new habitat/ecosystem • Strengthen ecosystem connectivity • Protection of endangered species	Urban Nature Atlas, NATURVATION

The benefits of ecosystem restoration activities can be evaluated by willingness-to-pay (WTP) analyses. MERCES undertook a WTP analysis for (marine) kelp forests in Norway, which show a positive and significant societal benefit associated with such restoration actions. However, the derived estimate of WTP does not reflect the total derived ecosystem service benefits of kelp forest restoration, which also include the restored kelp forest acting as a carbon storage facility and contributing to coastal protection by diminishing the impact of storm surges (Hynes et al., 2019: 17). Moreover, MERCES investigated restoration costs on the basis of case studies, such as on macroalgae restoration focused on three interventions: removal of sea urchins, (ca. 14 EUR/100m^2) which prevent the return of kelp; transplantation of seeds or branches (ca. 10,500 EUR/100 m^2); and using artificial reefs (ca. 42,000 EUR/100 m^2) (Groeneveld et al., 2019).

OPENNESS assessed the cost-effectiveness of restoration measures by quantifying benefits resulting from the removal of invasive alien plants. This measure contributes to the improvement in the habitat conservation status, and can subsequently lead to an enhancement of the supply of ecosystem services and to support the conservation of threatened species. The results showed that when accounting for the cost-effectiveness in per capita terms, the GI identified in the "nature for people" scenario was more beneficial (as compared to the nature for nature, and nature to restore scenarios), given the large share of the population that would potentially benefit from such ecosystem restoration. This provides further evidence that ecosystem restoration can contribute to improving multi-functionality while providing increased benefits for society (Vallecillo et al., 2016).

Providing evidence on the cost-effectiveness of biodiverse NBS can help to trigger financing and investments from public as well as private actors such as housing and development companies (see examples below). In addition to public funding programmes to foster NBS and biodiversity in urban and rural areas, a range of innovative financing and business models have been applied, which can benefit also other types of NBS. Examples include:

- Participatory budgeting – process, which allows citizens to make decisions about how a public budget is spent and gives them an opportunity to contribute their own ideas. In the context of promoting biodiverse NBS, a portion of a participatory budget can be dedicated to urban biodiversity projects (Iwaszuk et al., 2020).

- Biodiversity offsets – assessing biodiversity losses and gains (e.g. due to infrastructure developments) also considering ecosystem services and relational values of people to determine net outcomes and create new habitats and/or increase the ecological value of existing areas. Farmers could be paid by developers to provide biodiversity. Conservation banking schemes can be established (OPERAS, 2018).

- Vacant space model – the government/municipality steps back and provides space for local initiatives and (social) entrepreneurship in unused urban public space, e.g. for community gardens and farming (SEEDS, 2015; Toxopeus et al., 2019).

- Local stewardship model – local NBS plots and trees are valued by citizens and businesses who are willing to protect and support nature in their neighbourhood based on the direct value and sense of identity and meaning that they derive from it (Dempsey and Burton, 2011; Toxopeus et al., 2019)

- Payments for Ecosystem services – addressing the societal demand for the delivery of some environmentally and socially beneficial outcomes in rural areas, i.e. certification schemes for organic farming, integrated conservation and development projects or premium price payments for traditional orchard meadows (Mantino et al., 2016).

The example from Portugal below illustrates how biodiversity supporting NBS can deliver a wide range of benefits, trigger innovative financing and be upscaled.

BOX 2. Sown biodiverse permanent pastures rich in legumes

Sown biodiverse pastures are a system of pastures developed in Portugal by Engineer David Crespo and promoted by a start-up called Terraprima. They are sown with mixtures of large numbers and varieties of seeds (up to 20), including native species, and the pastures can be kept for at least 10 years. These seeds contain a high proportion of legumes and can generate higher yields than those occurring in conventional seed systems. They constitute an alternative agricultural system that optimises both the economic and environmental performance of farms and are relevant for areas susceptible to agricultural abandonment and desertification.

Benefits: Legumes fix nitrogen directly from the atmosphere through microorganisms, which avoids the use of nitrogen fertilizers and linked environmental impacts and high greenhouse gas emissions. Soil organic matter and soil fertility is increased due to higher productivity, reducing soil erosion and increasing water holding capacity. It was estimated that > 6,5 CO_2/ha*yr of atmospheric carbon are sequestered in the long-term (Teixeira, 2010). Wild biodiversity such as insects, birds and soil biodiversity show similar levels as those occurring on natural grasslands (Teixeira, 2015).

Implementation: The Sown Biodiverse Pastures project (2009-2014) provided over 1,000 Portuguese farmers with seed mixtures adapted for specific soils, technical support and knowledge to better manage their 50,000 ha of land. The project sold 1 million tonnes of CO_2 to the Portuguese Carbon Fund, an operational instrument, which intends to finance several actions with positive returns regarding a decrease in GHG emissions. Farmers involved benefitted from ca. 80% of these economic returns, with the rest being spent on project management, technical support and monitoring.

In Lisbon, such biodiverse extensive meadows were implemented as components of NBS, replacing irrigation-intensive lawns, and are now part of the green corridors. The main objectives of these NBS was to increase diversity of species, help to cope with rainwater management and soil degradation, requiring less resources (water and nitrogen fertilisers) for its maintenance. Oppla case study: Nature-based Solutions Enhancing Resilience through Urban Regeneration).

Figure 12. Biodiverse meadow, Lisbon Image: CML

4.5. POLICY RECOMMENDATIONS AND RESEARCH GAPS: BIODIVERSITY AND NBS

4.5.1. Policy recommendations (biodiversity and NBS)

A number of recommendations have been developed to promote the mainstreaming of NBS in biodiversity and wider sectoral policies, thereby enhancing their contribution to diverse policy objectives including fostering a sustainable societal transformation. Potential instruments and means to put these recommendations into practice are also listed:

- *Cross-policy* integration and support: Mainstream biodiversity through the implementation of NBS across policies (e.g. natural water retention measures in flood risk management plans or adaptive NBS as part of regional/national adaptation strategies and plans) and significantly increase EU-level strategic investments and earmarked funding to do so across relevant policies and funding instruments (e.g. LIFE+, CAP (agri-environmental-climate measures, Natura 2000 support measures), ERDF, INTERREG).

- *Protected area network:* Expand and improve the current "functional" protected area network to ensure its representativeness, resilience, coherency, connectivity and increase in positive impacts on habitat and species conservation status by restoring degraded ecosystems and preserving and managing protected areas in a sustainable way (building on Art. 2 and 6 of the Habitats Directive), creating new habitats and GI, and designating existing areas (e.g. natural and semi-natural non-protected areas) as protected areas (building inter alia on Art. 4). Specifically, targets should be established for protected areas and non-intervention areas (so called strictly protected areas), including terrestrial, freshwater and marine ecosystems.

- Conservation objective setting: Improve coherence between conservation objectives and conservation measures, not least by ensuring spatially coherent objective setting across the national scale and appropriate accompanying monitoring schemes with measurable indicators (e.g. via EU Biodiversity Strategy 2030, national biodiversity strategies and prioritised action frameworks, action plans for selected habitats listed in the Habitats Directive). Improve conservation and restoration objectives for Natura 2000 sites by defining specific, measurable, comprehensive and realistic objectives, which can be monitored and evaluated.

- *NBS and GI:* Establish a coordinated approach[10] to NBS/GI deployment at EU and MS level, using spatial data to map, select, assess and manage priority areas and ensure functional connectivity for species, cumulative benefits of interacting areas, ecosystem service delivery, biodiversity protection, and human health benefits. This can be done by building on existing spatial data from JRC/ETC-ULS and national/regional NBS/GI strategies and action plans. Coordinate systematic assessment and frequent monitoring of the network at EU level and mandated as reporting from site scale, linking to the status of habitats and species and integrated valuation[11] of ecosystem services through common assessment guidelines. Such action could also entail a further development of the MAES initiative towards a more integrated valuation.

- *Building capacity:* Develop and actively disseminate guidance materials, streamlined tools and approaches for Member States, regions and cities to guide NBS mainstreaming (which sectoral policies can be supported through NBS), monitoring (e.g. indicator selection), design, funding (e.g. available EU financing instruments) and assessment, using existing platforms such as Oppla, Network Nature, and the thematic websites of the European Commission. Develop guidance to foster polycentric governance and integrated management concepts for biodiversity and natural resource management at regional/municipal level, e.g. novel arrangements in public administration that involve organisations to include not only flood and landslide protection, but also nature conservation, urban planning, water quality, waste management, tourism, recreation, and other administrative responsibilities. In addition, policies should be designed to: support empowerment and innovation

[10] Entails a coordinated planning and implementation process taking into account different demands and corresponding benefits/services to be delivered.
[11] i.e. accounting for the plural values of biodiversity and ecosystems that should be used to ensure that social-cultural values are adequately considered

(e.g. focus on outcomes and results; encourage engagement in management); focus on capacity building, facilitation and multi-actor engagement; encourage more cooperation and collective approaches; and foster local governance.

In addition to these recommendations, there is an urgent need to reflect more on the linkages between biodiversity, nature and people in European policy and research frameworks moving forward, taking relational values more strongly into account alongside economic and intrinsic values in objective setting and practice. Specifically, relational values refer to values of connectedness with nature that create meaningfulness in the lives of people and communities and nations (i.e. place attachment, identity and social belonging).

4.5.2. Research and innovation gaps (biodiversity and NBS)

A large body of evidence already exists to support the design, implementation and monitoring of NBS and measure contributions towards various objectives. However, this project review identified a number of remaining research and innovation gaps which should be addressed in future research programmes, such as Horizon Europe, to optimise NBS effectiveness, particularly regarding the delivery of biodiversity benefits. Questions requiring further research include:

- How should NBS be designed and implemented to effectively contribute to the protection of biodiversity (habitat structure/condition and species composition) at different scales, while also delivering other benefits (e.g. climate change mitigation and adaptation, human health, social cohesion)? How does NBS design impact the relationship between biodiversity, ecosystem functioning, ecosystem service delivery and human health (focusing in particular on functional aspects of biodiversity and impacts on species)? What trade-offs are generated based on different designs, and how can these be taken into account during decision-making processes? What are the most suitable areas for restoration and/or extending the current network of protected areas that can not only protect biodiversity, but also deliver multiple additional benefits (e.g. climate change mitigation and adaptation, recreation, sustainable agriculture production, human health)?

- What role can NBS play in the development and implementation of no net loss approaches addressing urban and rural biodiversity? What effective 'no net loss' approaches and systems exist for urban biodiversity within and beyond Europe? How can such approaches be standardised and translated into binding regulations, and at which scale is most effective?

- What are the costs and multiple benefits generated by different types and scales of NBS and hybrid solutions (combining grey and natural elements) aiming to protect biodiversity as a primary objective? How can the approaches and indicators for measuring these contributions towards biodiversity and other objectives be improved and streamlined?

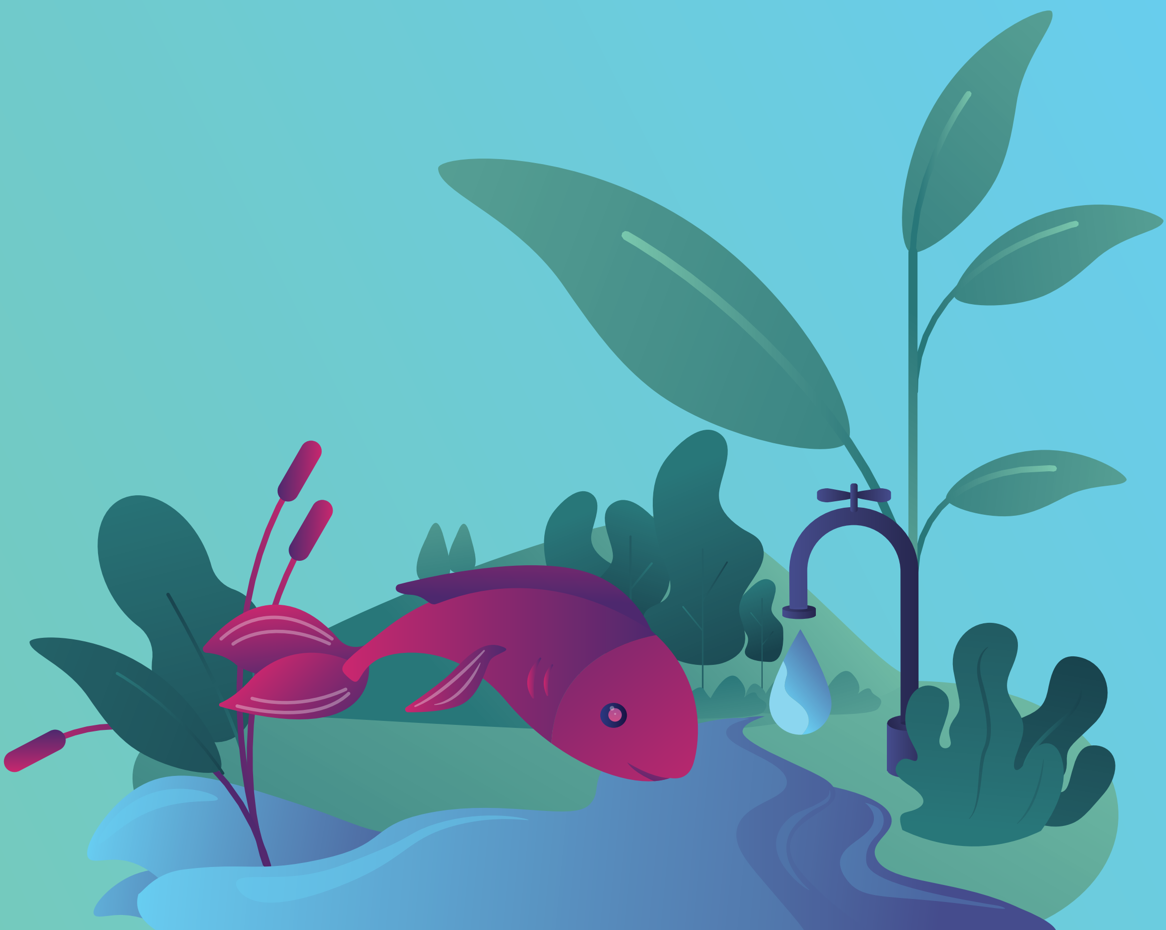
- How is climate change foreseen to impact ecosystem health and individual species across the EU? How can NBS support adaptation efforts to cope with these impacts? Alternatively, what is the potential contribution of biodiverse NBS to mitigate climate change? How can EU policy support NBS uptake within the current framework or foster further efforts within new or updated policies and initiatives (e.g. EU Adaptation Strategy; EU Biodiversity Strategy to 2030; European Green Deal) to mitigate and support biodiversity's adaptation to climate change?

- How can current climate, energy and agriculture models better account for potential impacts on and changes in biodiversity and the delivery of ecosystem services, therewith contributing to the revision of associated policy frameworks? How can models contribute to improved decision-making as well as to reducing unintended negative side effects from and increasing positive benefits for other sectoral policies?

- What innovative management approaches can be applied in protected areas to help overcome key current challenges, e.g. a lack of viability or sustainability due to lack of cost-effectiveness, value for money, societal acceptance or other issues; failure to deliver expected outcomes in terms of biodiversity protection?

Nature-based Solutions
Improving Water Quality & Waterbody Conditions

Tom Wild



5. NBS FOR IMPROVING WATER QUALITY AND WATERBODY CONDITIONS

5.1. BACKGROUND AND STARTING POINTS FOR THIS ANALYSIS

This section summarises outcomes relating to water quality and waterbody conditions from the EC initiative on the valorisation of NBS projects. It is an abridged version of the separate report (Wild, 2020) which is accompanied by a shorter 'factsheet'. EU projects were scanned for results pertaining to key areas such as Water Framework Directive (WFD) implementation, cross-compliance with the Common Agricultural Policy, catchment management, diffuse pollution and waterbodies. Stakeholders' priorities for this work were to analyse EU NBS projects and their transferable results. Evidence from these projects is framed within knowledge from the literature in the realm of water policy, situating the results to give as full a picture as possible about the state of the art with relevant NBS.

On commencement of the project, a stakeholder workshop was held in Brussels (on 3rd December 2020) with a range of experts, policy officers and research managers. During this workshop it was agreed that main priorities for this review would include a range of policy development priorities, practical implementation opportunities and challenges, and knowledge gaps stemming from EU NBS projects and the wider literature. The priorities discussed by the stakeholders and experts were as follows:

1. information is needed on decision support protocols based on real cases of NBS implemented as well as examples demonstrating the integration of green and grey infrastructure and their contributions in addressing city challenges.

2. guidelines are needed to help translate evidence into local action, by providing summaries of findings in ways that can support knowledge exchange across sectors and disciplines.

3. stakeholders highlighted requirements for information on NBS' status impacts (chemical, ecological, hydro-geomorphology, temperature etc.) and contextual data regarding the state of the environment within cities and regions.

4. specific evidence is sought about the removal of pollutants by vegetation and soil (in both urban and rural environments).

5. it is important to gain better insights into how NBS projects improve the conditions for life, for instance in heavily modified water bodies, by improving aquatic and

riparian habitat e.g. spawning ground, and for instance by mitigating impacts in water levels (baseflows, etc.).

6. evidence in the form of robust case studies is needed about how regions organise and link with end-users, e.g. in promoting source control, stormwater treatment, and comprehensive catchment management approaches.

7. a cross-cutting issue affecting all of the above priorities is to understand how successes in natural water treatment systems are being scaled up, what are the constraints to this, and how are those limitations being addressed.

8. a greater emphasis should be provided about areas where there is convergence on evidence (e.g. on drivers, pressures, state, impacts and responses), rather than areas where little is known or there is uncertainty.

9. key knowledge gaps and evidence needs should be summarised, notwithstanding the desired primary focus on areas of consensus and knowns.

During the Brussels workshop (December 2020) it was decided that the information from NBS projects should be situated within this knowledge from the literature to give as full a picture as possible about the state of the art with NBS, within this realm of water policy (noting that flooding is covered in section 6 of this report). Thus the above priorities should themselves be seen within the wider context of key policy developments, synopsis documents as outlined in section 1, and other reviews that signpost current knowledge and future directions.

5.2. OVERVIEW OF MAIN WATER POLICY DEVELOPMENTS AND LINKS WITH NBS

Water management laws in European countries stem back centuries (for instance in England, dating back at least to the 1427 Sewers Act) and perhaps even before the codifications of rules and measures in Roman times to prevent illness among the population by public sanitation measures. Urban water management interventions for foul and surface water management are clearly viewable at Minoan sites in Crete. The terracing of land and aqueducts at Macchu Picchu in Peru demonstrate advanced knowledge of the relationships between agricultural productivity, erosion and water retention. Conversely, drainage ditches dug in the Romney Marshes in the UK's South East were the subject of legal disputes as far back as the 13th century.

Water management can therefore be seen as a central concern for civilisations throughout the ages and across our planet. However, human-induced global warming, climate change and environmental degradation caused by pollution and habitat loss have all placed greater emphasis still on how societies organise the management of access to, or protection from, water - along with interest in the legal frameworks handling water-related disputes between people, communities, cities, regions and countries or even continents. EU Directives such as the WFD and the Floods Directive therefore represent significant developments in a long line of attempts to manage water sustainably, and relevant NBS can be usefully viewed in this context. Water laws are important.

EU water policy has delivered significant improvements to water quality over the past four decades (EC, 2019a): According to the EC, "it is increasingly possible to reconcile life in a densely populated continent, and a growing economy, with a progressive improvement of water quality" and that this has been achieved thanks to EU water law, the efforts of Member States and support through EU funding. It can be added that technological developments and increased understanding has also been partly responsible for these improvements. Furthermore, NBS innovations offer new opportunities to further respond to the increasingly important WFD challenges and remaining water management problems e.g. harmful diffuse pollution and hydro-morphological damage, and the rising costs involved in fixing their impacts.

Hering et al. (2010) note that from a scientific perspective, the implementation of the WFD has greatly increasing knowledge on the ecology of Europe's waterbodies, supported by masses of monitoring data generated for this purpose. According to the OPENNESS project, the WFD is one of very few regulatory frameworks requiring comprehensive systems for measuring environmental impacts (Schleyer et al., 2015). The policy analysis undertaken by that project includes a useful summary of the main characteristics of the WFD (Winkler & Schleyer, 2015).

The EU Water Legislation Fitness Check (EC, 2019b) and supporting study (Trinomics & Wood, 2019), provides a comprehensive policy evaluation of: the WFD, the Floods Directive, the Environmental Quality Standards Directive (EQSD), and the Groundwater Directive (GWD). It is closely linked to the evaluation of the Urban Waste Water Treatment Directive, UWWTD). The Fitness Check assessed whether the Directives were fit for purpose by examining performance against five (Better Regulation) criteria: effectiveness, efficiency, coherence, relevance and EU added value. It concluded that the Directives have led to a higher level of protection for water bodies and flood risk management than could have been expected without them, but on the other hand, that implementation has been significantly delayed and less than half of the EU's water bodies are in good status, even though the deadline for achieving this was 2015 (bar exemptions). Factors contributing to the effectiveness of the Directives in progressing towards their objectives include: (a) the list of priority substances; (b) the (binding) cross-references to WFD objectives in other EU policies; (c) EU funding; (d) the widely applicable non-deterioration principle; and (e) the Directives' monitoring requirements (EC, 2019b).

Hindering factors to successful implementation reported in the Fitness Check include national and local governance frameworks, and possibilities and models for public participation in the WFD River Basin Management Plans (RBMPs). Important from an NBS perspective, it notes that good status depends not only on mitigating new and emerging pressures, but also on retrofitting restoration measures. Also of relevance to the NBS agenda is its conclusion that slow progress to meet WFD objectives is partly due to insufficient funding and inadequate integration of environmental objectives in sectoral policies. Finally, good status of water bodies also critically depends on the full implementation of other pieces of EU legislation (e.g. Nitrates Directive and UWWTD), as well as better integration of water objectives in other policy areas such as agriculture, which has not yet happened at the scale necessary. The analysis in this Fitness Check finds that there are trade-offs between the required flexibility, cost-effectiveness of measures, and the resulting complexity.

BOX 9. Drawing on FP7 MARS project findings, Carvalho et al. (2019) highlighted significant strengths of the WFD in its integrative approach to ecosystem health, and in how it promotes comparable EU-wide assessment. They suggest that WFD outcomes assessment does not adequately address causes of failure, and that the 'one-out-all-out approach' whereby water class is downgraded (from high or good ecological status to moderate, poor or bad) using a wide range of parameters, is over-precautionary.

Carvalho et al. (2019) note that an important success of the WFD is that it provides the conditions for integrative management at the river basin scale, and in its dealing with point source pollution problems - but they also emphasise that insufficient measures have been taken to address diffuse pollution and combined sewer overflow problems. Perhaps most importantly for NBS, they stress the need for much stronger implementation of measures, notably those involving mechanisms to improve engagement and those incorporating ecosystem-based approaches.

The 'one-out-all-out' protocol may have unintended consequences of exacerbating environmental degradation, in areas where significant polluting industries were clustered (Fairburn et al., 2005; 2009) and where communities already suffer from the loss of ecosystem services. It may also lead to 'winner takes all' scenarios whereby cherished waterbodies in more affluent areas receive greater protection, thereby worsening social and environmental injustice. Notably, the key exception to the ambitious WFD target for all water bodies to reach good status is the derogation in place for heavily modified water bodies (HMWBs) which, as a result of physical alterations by human activity, are substantially changed in character and cannot, therefore, meet "good ecological status" (see also Steyaert & Ollivier, 2007).

BOX 10. Research in FP7 WISER as reported in Hering et al. (2010) concluded that the WFD timescales to obtain good ecological status in all surface waters have been overambitious (the deadlines being for 2015 bar exemptions, and by 2027 in all cases). They warn that restoring water quality and habitats does not automatically mean that sensitive species will reappear and that these outcomes depend upon source populations, colonization paths and sufficient time for recovery. The importance of efforts to prioritise measures according to recolonisation potential are thus highlighted (further information on biodiversity and habitat enhancement relating to aquatic and riparian ecosystems can be found in Section 4).

The 2019 Fitness Check follows an earlier 'Water Blueprint' review of the EU's freshwater policy (EC, 2012). A critical discussion in the lead-up to the Blueprint review was around the possibilities and models for public participation in WFD River Basin Management Planning (RBMPs) and appropriate scales for, and means of, engagement. Article 14 of the WFD makes provisions for public participation, following the Aarhus Convention (UNECE, 1998). However, as for the European Landscape Convention (e.g. Jones et al., 2007; Conrad et al., 2011) there has been much debate about real or perceived gaps between rhetoric, practice and reporting.

BOX 11. Verwiej et al. (2016) describe tools developed in FP7 projects OPENNESS and ROBIN, to support quick, participatory methods to identify problems and scope WFD policy processes. Using the tools in different workshop situations, they report that participants were able to process knowledge usually provided in briefs and reports, to develop a joint understanding of the main interactions and impacts and to develop a problem statement and solution space in a reduced lead time. However, the paper also notes that the method heavily relies on the availability and quality of spatial data ("If the data is of poor quality you will also get poor results") - a problem not unique to this setting, which highlights questions of inequity in the voice and power of given to different stakeholders through the use of advanced mapping tools and via access to spatial data. Oppla summarises an applied case of the use of the tools to develop an adaptive management plan for the lower Danube River, Romania.

Partly in answer to critiques that WFD strategic planning processes can be remote or overly bureaucratic, some countries have tried to develop more direct ways to involve people in water management decision-making at the local- to catchment- levels (e.g. Defra, 2013; Gusmaroli et al., 2008). The success of such approaches can be usefully questioned as regards the depth of engagement of 'ordinary' i.e. layperson citizens in water management issues (e.g. see Westling et al., 2014).

Furthermore, the fragmentation or 'dis-integration' (Ashley, 2015) of responsibilities for water management, citizen engagement, spatial planning (Rijke et al., 2012) and particularly maintenance has led to missed opportunities for win-wins in terms of the regeneration of river corridors (Wild et al., 2008) in cities. Melbourne provides an interesting case where holistic attempts have been taken to transition to a water sensitive city, in part stimulated in the 1990s by diffuse pollution control measures that changed community attitudes towards urban amenity and ecological health (Brown et al., 2013), and where this transition is accelerating but incomplete (Ferguson et al., 2013). Other important examples where urban water management has been integrated with urban regeneration and wider spatial planning issues include Zurich (Wild et al., 2011; Broadhead et al., 2013) and the Sponge Cities Programme in Chinese cities such as Changzhou (Li et al., 2018; Chan et al.; 2018).

BOX 12. The Interreg IVC ERCIP project on European River Corridor Improvement Plans developed shared understanding of different engagement models, allowing regional agencies with environmental protection duties to work in partnership with local authorities with their emphasis on the social and economic wellbeing. Further guidance on how to promote public participation in WFD implementation via the cooperation of various institutions and organisations was provided by Interreg RhineNet and through the large-scale river restoration delivered by LIFE+ 'My Favourite River' on the River Neckar, Stuttgart.

The recent Assessment Report on the implementation of the WFD and the Floods Directive Management Plans (EC, 2019c) emphasises the strategic issues of national-scale governance, the characterisation of river basin districts, and the monitoring and assessment of water bodies. It also provides an overview of progress to achieve environmental objectives and exemptions, implementation via the 'Programmes of Measures' (PoMs) and the designation of HMWBs and definition of Good Ecological Potential. The primary focus on procedural rather than (locally) substantive issues reflects the principle of subsidiarity, in that RBMPs are developed by Member States, which are not instructed by the EC on content. The 2019 Assessment notes "the path towards full compliance with the WFD's objectives by 2027, after which exemption possibilities are limited, seems at this stage very challenging"; it highlights that in most Member States, reference conditions have not been established for all waterbody types (rivers, lakes, transitional and coastal) and for all quality elements and for all quality elements (EC, 2019c). This challenge, and calls to establish an EU-wide monitoring network of reference sites, had already been highlighted 10 years ago (Hering et al., 2010).

This lack of progress perhaps reflects a wider concern that although 'natural' or 'pristine' reference conditions for water bodies may be a desirable notion, in reality this quest for characterisations of waterbodies unaffected by anthropological impacts is fraught with difficulty and might even be unachievable. The ways in which human beings have altered water cycles and waterbodies are complex and manifold, having taken place over millennia, in almost endless layers of change. Nesshöver et al. (2017) previously highlighted this central challenge around "where to draw the line as to what is considered as 'nature' or 'natural'". Concepts from the NBS literature may therefore prove increasingly helpful to the future development of the WFD and associated water policy (e.g. Eggermont et al.'s (2015) framing of restoration as a continuum of actions that seek to habitats and a range of ecosystems functions, rather than recreating 'pristine' original conditions).

BOX 13. In H2020 AMBER Jones et al. (2019) established that only 3% of the total river network of Great Britain is fully connected. Only 1% of the rivers in England, Scotland and Wales are free of artificial barriers. These findings show that most catchments in Great Britain are heavily fragmented, providing a much-needed critical starting point to assess the impacts of waterbody modification across ecologically relevant spatial scales.

Reporting compliance at the highest level, the 2019 Assessment identifies where the EC has pursued targeted legal action to enforce WFD implementation. These fall into the broad classes of (1) Enforcement of the deadlines; and (2) Correct transposition – i.e. non-conformity of the national legislation transposing WFD requirements (EC, 2019a). The latter category is further broken down into (a) Bad application cases, (b) failure to meet reporting requirements, (c) Targeted follow-up to the assessment of RBMPs, and (d) Cases arising from complaints (including those linked with public participation in line with the Aarhus Convention as described above). Case law from the Court of Justice of the European Union (ECJ) highlights that throughout Europe, injunctions have been taken that relate to several underpinning aspects that are fundamental to the WFD.

Overall, around 40% of the surface water bodies are in good or better ecological status, while 60% did not achieve these classes. The ecological status of natural water bodies is generally better than the ecological potential of heavily modified and artificial water bodies, particularly rivers and transitional waters (EC, 2019a). EU Member States are permitted exemptions to WFD Article 4, where reasons for derogations are given (according to specific sub-articles[12]). The 2019 Assessment highlights that WFD Article 4 exemptions are still being used extensively, with around half of Europe's water bodies currently under an exemption, and with certain exemptions being applied more often in the second cycle of river basin management planning than in the first in several Member States. Many of these Article 4(5) derogations involve HMWBs. Less stringent objectives under Article 4(5) can be applied to specific water bodies when they are so affected by human activity or their natural condition is such that the achievement of good status would be infeasible or disproportionately expensive (CIRCABC, 2017).

BOX 14. The H2020 PHUSICOS team reported on an 11-year participatory process leading to successful delivery of the River 'Isar Plan' in Munich, Germany. Budgeting €35m to restore 8 km of river, the project reached goals to improve flood protection, ecological status and water quality. Adopting a Living Lab approach, the recreational potential of the riverine area was increased, and the alpine river character re-established (see also LIFE Restore river wiki here).

The 2019 Assessment notes that good progress has been made since the first RBMPs in the establishment of reference conditions. However, gaps still remain, since in most Member

[12] e.g. Articles: 4.4 - the extension of the deadline (good status must be achieved by 2021 or 2027); 4.5 - the achievement of less stringent objectives under certain conditions; 4.6 - the temporary deterioration of the status in case of natural causes or "force majeure" i.e. severe floods, prolonged droughts, accidents; 4.7 - new projects or modifications to the physical characteristics of a surface water body or alterations to the level of bodies of groundwater, or failure to prevent status deterioration of a body of surface water.

States reference conditions have not been established for all water body types. Notably, the quality elements whose type specific reference conditions showed the most significant gaps for surface water body types were found to be the hydro-morphological ones. This is particularly problematic, because derogations under Article 4(5) are often based on hydro-morphological modifications. This may allow for circular arguments to delay the implementation of measures to restore ecological potential, particularly in urban watercourses. In the current work programming round of the Common Implementation Strategy[13] it will therefore be important to consider HMWBs issues from the viewpoint of scaling up practical actions, and sharing information about successful implementation of schemes that have succeeded in generating multiple values and co-benefits for Member States, beyond WFD outcomes.

The CIS was tasked with work to investigate the financing of measures and producing a report on good practices for the identification of investment needs and funding sources for WFD Programmes of Measures or PoMs (CIS, 2018). Its Working Groups were required to exchange information and good practices on PoMs, including a library of measures that can be used towards reaching good status. The Flooding working group refers specifically to the use of NBS in this regard.

BOX 15. FP7 OPENNESS investigated river basin management planning in five member states across differing institutional and governance arrangements. Grizzetti et al. (2016) studied ecosystem service concepts, highlighting benefits of intersectoral integration, synergetic uses of waterbodies, multi-functionality of measures, biodiversity conservation support and a need for more comprehensive economic valuation methods. They stressed that high expectations placed on water management authorities were accompanied by a lack of practical guidance to support the application of ecosystem service concepts.

5.3. HOW NBS PROJECTS ADDRESS WATER POLICIES AND SUPPORT IMPLEMENTATION

The Fitness Check (EC, 2019b) notes that success with next round of PoMs will be critical to the achievement of environmental objectives by the 2027 deadline. It stresses that the EC needs to work with Member States and help them to improve implementation at the lowest possible cost, e.g. by “sharing best practices on green infrastructure and cost reduction of pollutants at source”. The ECJ injunctions relating to the fundamentals of WFD implementation also serve to highlight that awareness-raising actions, and the sharing of good practices, remain extremely relevant and their importance should not be neglected. The 2019 Assessment Report (EC, 2019a) stresses the importance of efforts that have “facilitated the development of networks composed of key stakeholders in order to increase public awareness of water issues and thus lead to better implementation on the ground”. The present report therefore summarises evidence of collaborative work to improve the characterisation of WFD issues and to better understand water-related problems, alongside what might be considered ‘hard’ evidence on the performance of novel NBS or more advanced policy developments.

[13] The 2019-21 Common Implementation Strategy Work Programme, drafted at the time of the Fitness Check (EC, 2019b) and WFD assessment report (EC 2019c) reconvenes several working groups (CIRCABC, 2018) including ECOSTAT, responsible for providing technical guidance on issues including hydro-morpology.

This conclusion underlines a key issue regarding how the successful implementation of international water policy requires efforts to integrate action across governance scales. Source control and other NBS interventions touch on the lives of citizens very directly, and can do so in both positive and negative ways depending on how these measures are implemented or funded. A particular concern therefore is how to bring together strategic top-down priorities for water management with bottom-up, participatory actions. Broad-scale strategies can deliver direct benefits to local communities most effectively (gaining and maintaining support) where those agendas engage with practical actions that people can see, touch and feel. This is an area in which H2020 NBS demonstrator projects bring new dimensions to water policy development. Online resources can usefully complement these local, physical demonstrators. To this end the EC's web-based service Communication and Information Resource Centre for Administrations, Businesses and Citizens (CIRCABC) seeks to support the joint implementation of the Water Framework Directive (WFD) by improving the information exchange at the local to transnational level. Similarly, online NBS platforms like Oppla have a key role to play.

The WFD requires that for each river basin district, reporting by Member States of PoMs must accord to 25 predefined 'Key Types of Measures' or KTMs (CIS, 2016) covering a range of social, environmental and economic controls and activities. The WFD further specifies that PoMs shall include as a minimum 'Basic Measures' (and 'Supplementary Measures' where needed). Strong complementarity and clear read-across exists between these requirements and a wide range of NBS responses, e.g. as elaborated in the EC's 2015 Expert Group report (EC, 2015a).

Basic Measures must as a minimum comprise measures to: a) implement existing Community water legislation and other environmental legislation; b) implement Article 9 (cost recovery); c) promote efficient and sustainable water use; d) protect drinking water quality and reduce level of treatment required; e) control abstraction from surface and groundwater; f) control recharging of groundwater; g) control point source discharges; (h) prevent or control inputs of diffuse pollutants; i) address any other significant impacts on status, in particular hydro-morphological condition; j) prohibit direct discharges to groundwater; k) eliminate or reduce pollution by Priority Substances; and (l) prevent accidental pollution (CIS, 2016).

Many H2020 NBS innovations, as well as those developed through other EU projects, can also be considered under the main (broad) categories of pressures on water bodies to be addressed by PoMs (EC, 2019a) reported as: (A) abstractions and water scarcity; (B) pollution from agriculture; (C) pollution from non-agricultural sectors (including nutrients, organic matter and chemicals); (D) hydro-morphological alterations; and (E) Cross-cutting measures. Notably, pollution from non-agricultural sectors includes a vast array of point-sources of wastewater and urban diffuse sources of pollution. Notably, exemptions for chemical status of waterbodies mainly relate to diffuse- and point- source pollution pressures.

Bearing in mind the current state of implementation of the WFD and other water policies, the subsequent parts of this section highlight areas where and how NBS can contribute to solving water-related societal challenges. In particular, this concerns how NBS can address: (i) point sources of pollution, including combined sewer overflows; (ii) urban drainage and stormwater quality, including urban diffuse pollution control; (iii) agricultural pollution, land drainage and soil erosion in rural catchments; (iv) hydro-morphology and the restoration of modified waterbodies; and (v) wider relationships with cohesion, regeneration, health and wellbeing.

5.4. THE EVIDENCE BASE ON NBS AND THEIR RELATIVE COST-EFFECTIVENESS

5.4.1. Point sources of pollution including combined sewer overflows

As regards the treatment of foul sewage and effluent, NBS such as constructed wetlands were traditionally viewed as providing the greatest contribution to waste water treatment at the tertiary or effluent 'polishing' stage, following physical removal of major solids, sedimentation digestion, and biochemical treatment. However, interest is also increasing in the use of NBS as source control measures either to prevent contaminants from entering water streams or to reduce flows of water and pollutants into the sewer system.

The EC evaluation of the Urban Waste Water Treatment Directive (UWWTD) concluded that overall it has been effective, that the reduction of organic matter and other pollution in treated waste water has improved water quality, and that although implementation has been expensive, the benefits clearly outweigh costs (EC, 2019d). It also notes that with more heavy rainfall events expected due to climate change, storm water overflows (including combined sewer overflows, CSOs) will be an increasingly important source of pollution and pressure on surface water bodies. The evaluation also notes that urban runoff, which is only covered by the UWWTD in connection with combined sewage, is an increasingly important source of pollution including heavy metals and micro/plastics. The evaluation also notes that the UWWTD is too old to deal adequately with new concerns, such as the pollution of water bodies by pharmaceutical residues and micro plastics in waste water systems.

Montalto et al. (2007) found that low impact development (LID) employing NBS such as sustainable drainage can usefully complement traditional stormwater management in dense, urban areas served by combined sewers. Under a range of cost and performance assumptions they show that systems integrating NBS-type interventions such as green roofs can achieve cost effective reductions in CSO spills, outperforming hard infrastructure storage tanks on cost grounds, whilst improving urban environmental quality. Engstrom et al. (2018) also report that green roof systems can deliver cost savings due to reduced stormwater flows and decreased CSO volumes and events, in turn decreasing nutrient and chemical pollution levels.

Davis and Naumann (2017) make the case for the use of sustainable drainage to address flooding and to reduce the impacts of CSO spills, drawing on the work of the FP7 RECREATE project, and quoting the comparative economic assessment of drainage options (sustainable drainage or SUDS, vs. conventional drainage) using the B£ST tool as reported in CIRIA (2015). Keeler et al. (2019) note that in cities with combined sewer infrastructure, bioswales, street trees and rain gardens can intercept, evaporate and infiltrate stormwater before it reaches sewer systems, decreasing the volume of water needing treated.

BOX 16. FP7 DESSIN's case study of the daylighting of the Aarhus River reports that enabling infrastructure including real-time control systems cost ~€47 million, with an operating cost of ~€600k/year. The benefits of opening the river and resulting water quality improvements were calculated to be €120 million. However, this valuation is limited to the benefit of opening the river in the central city, and does not include the social benefits of water quality improvements to the lake, harbour and upper river between the lake and city centre (see Jensen et al.'s (2014) FP7 PREPARED report).

Referring to studies of stormwater removal from combined sewers pertaining to the Thames Tideway Sewer Tunnel, Ashley et al. (2011) highlight the need to consider the wider multi-value benefits of green-infrastructure based SUDS. The City of Zurich is estimated to have reduced waste water treatment costs by removing stream flows from sewer networks, such that each litre per second of river flows diverted saved around 5,000 CHF per year in treatment costs (Wild et al., 2011). Broadhead et al. (2013) note that in the same case, 'captured' stream flows in sewers contributed 7-16% of the baseflow reaching wastewater treatment works. Eckart et al. (2017) report that the Philadelphia Water Department's 'Triple Bottom Line' study assessed CSO control options for a 40 year period, determining that the city-wide total present value benefits of using GI ranged from USD1.9 billion - USD4.5 billion depending on the extent used (25% to 100% respectively) in removing stormwater from the combined sewerage system.

Figure 13a-c. Daylighting may solve combined sewer floods due to full/blocked culverts (Images: Tom Wild)

The above cases relate to the integration of NBS with wider water infrastructure. However, the UWWTD evaluation (EC, 2019d) concludes that individual and other appropriate systems may be substituted for centralised collection systems. It highlights that such 'off-grid' systems can become a problem if badly managed and unmonitored, but that they may sometimes offer a useful cost-effective alternative.

BOX 17. Liquete et al. (2016) report that NBS for water pollution control at Gorla Maggiore, Italy performed equally or better than the alternative grey infrastructure for water purification and flood protection. Having a similar cost, the NBS entailing 'end of pipe' constructed wetlands to treat waste water from CSOs, together with the surrounding park, provide additional benefits including wildlife habitat and recreation provision (integrated valuation and multi-criteria analysis undertaken in FP7 OPENNESS with the EC Joint Research Centre).

Masi et al. (2017) suggest that 'on-site' treatment by constructed wetlands allows continuous treatment and therefore higher pollutant mass removal compared to conventional (hard/concrete) storage tanks, without presenting negative side effects in operation or social acceptance. They stress the need for statistical analysis of hydraulic and pollutants loading rates and that new designs should be at all times supported by detailed understanding of event mass removal rates and effluent concentrations linked to specific event volumes and pollutants loading rates. Similarly, Garfí et al.'s (2017) life-cycle assessment of constructed wetlands and high-rate algal pond systems concluded that these were less expensive alternatives to conventional wastewater treatment systems, which come with high electricity and chemicals consumption requirements.

TABLE 16. The Water JPI (Joint Programming Initiative) is supporting many projects delivering innovative and transnational research covering a range of issues in managing water with NBS:
ATENAS, allying technology, nature and society for integrated urban water management.
RAINSOLUTION, improving city climate change resilience whilst avoiding material depletion.
DESCIPHER, on the integration of NBS within airshed and river basin management, to address urbanisation, climate change, air, soil and water quality, and ecosystem services.
FLOODCITISENSE, FLOODLABEL and GREEN BLUE CITIES, addressing the topic of urban flooding in different dimensions including early warning, multifunctionality and smart tools.
IFWEN, assessing changes in the food-water-energy nexus using urban BGI management.

5.4.2. Urban drainage, stormwater quality and urban diffuse pollution control

The EEA State of Water Report (2018) provides an overview of the identification of significant pressures and impacts at EU level, and gives an indication of the relative importance of diffuse pollution, where known. It shows that diffuse source pollution affects 38% of all surface water bodies (c.f. point source pollution which accounts for 18% of degraded waters) in Europe. Most countries report diffuse sources of pollution as being a pressure for groundwater (24 out of 25 Member States). Diffuse pollution impacts may also be linked with waters in unknown condition: according to the EC (2019a), although the percentage of water bodies that are of unknown chemical status has decreased since the first RBMPs (from 39% of all surface water bodies to only 16%), some Member States have more than 60% of water bodies of unknown status (Bulgaria, Denmark, Estonia, Latvia, Portugal).

Generally, greater progress has been made to address point-sources problems than diffuse sources of pollution in Europe, yet measures to prevent or control inputs of diffuse pollutants are to be classed as 'basic' measures in WFD PoMs. Progress to address diffuse sources of pollution remains slow and patchy geographically. Historically, diffuse pollution in European and other countries has been vastly underreported, poorly understood, under-estimated as a challenge, and masked by other pressures, both in urban and rural catchments (Novotny & Olem, 1994; D'Arcy et al., 2000; Wild et al., 2003; Ellis & Mitchell, 2006). A particular issue around road drainage is that many Priority Substances are not removed from stormwater using conventional drainage structures or via settlement e.g. using gully pots.

To tackle diffuse pollution, the WFD requires the implementation of basic measures under Article 11(3)(h) to prevent or control the input of pollutants from agriculture at source. Such basic measures are reported for all assessed Member States but not for all river basin districts, and not for all diffuse pollutants (sediments, phosphorus, pesticides, nitrates, microbiological/bacteriological and other pollutants). Non-agricultural sectors contributing to pollution include atmospheric deposition, storm overflows and urban run-off, among others. Key types of measures to address these problems are required to include: (i) Measures to reduce sediment from soil erosion and surface run-off (KTM17); and (ii) Measures to prevent or control the input of pollution from urban areas, transport and built infrastructure (KTM21). Slow progress is being made across Europe to implement and especially to retrofit such measures. Thus, urban diffuse pollution impacts can be expected to become an increasingly important consideration as will be the potential role of NBS in taking forward Zero Pollution Europe, in freshwater, estuarial and marine environments (and thus the Oceans Protection elements of the Green Deal).

BOX 18. The EC recently opened a Call for Proposals on natural treatment solutions for water security and ecological quality in cities. The H2020 'strengthening international collaboration' Call SC5-27-2020 launched in November 2019 will fund projects starting after 2020. It notes that "Surface and groundwater in cities and downstream urban areas may suffer serious pollution from point and diffuse sources from upstream and in-catchment which might have a negative impact on the ecology, quality of life and land values in the city. Furthermore, urban runoff, storm water and wastewater represents a threat to water quality because of the pollutant load it conveys. Enhanced nature-based treatment solutions (such as artificial wetlands and lakes, bio-filtration, etc.) have the potential to remove pollutants from water (e.g. storm water, urban runoff, river water, wastewater) that will lead to improved water quality and water use efficiency."

Pollution from urban non-point sources is one of the main reasons for failure to reach WFD water quality objectives set for waterbodies, but NBS in the form of sustainable drainage (SUDS) are available to reduce diffuse pollution (Mitchell, 2005). Pollutant loads in urban stormwater have long been studied (e.g. Marsalek, 1991) and urban diffuse pollution problems have been well quantified (e.g. Novotny and Olem, 1994). Effective treatment of urban stormwater runoff can be achieved using specific SUDS-type NBS in combinations set out in the stormwater management train (CIRIA, 2000; 2001; 2015). Specific percentages of nutrient removal can be predicted (Clary et al., 2017a) along with associated performance (Wong, 2006) in improving receiving water quality.

BOX 19. OPPLA describes an ambitious SUDS scheme at Southmead Hospital Brunel Building in Bristol, England. NBS constructed include six sedum green roofs and rain gardens, created to slow down rainwater collected from roofs and used for grounds maintenance and irrigation. Car park runoff is cleaned by 444 m of swales, prior to discharge via four attenuation ponds providing excellent invertebrate biodiversity. The scheme, recognised as an NHS Forest site, includes >700 trees and shrubs in small coppices and orchards. The NBS are reported to reduce surface water runoff by almost 40% and water consumption by 25%, leading to an annual saving of ca. £130,000.

Green roofs can deliver significant improvements in water quality (Berndtsson, 2010). SUDS such as bioswales and bioretention perform effectively in filtering pollutants out of stormwater flows further improving water quality downstream (Davis et al., 2001; Everett et al., 2015). Chan et al. (2018), quoting Qin et al. (2013), highlight that NBS such as bio-swales, rain gardens, pervious pavements and green roofs can mimic natural hydrological responses and absorb urban stormwater through soil infiltration, stormwater retention, storage and purification, thereby protecting groundwater and improving runoff water quality.

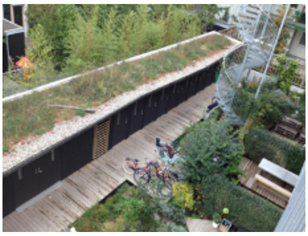
Clary et al. (2017a) report that most SUDS-type NBS are effective in removing metals such as total copper and reducing concentrations of total suspended solids and oils, but a more mixed picture emerges for the removal of bacteria, nutrients and some metals such as dissolved lead and arsenic. SUDS implementation is becoming widespread in many EU countries, but their effective combination within an integrated chain or hierarchy of 'source controls, site controls and regional facilities' remains rare, a phenomenon which has been known about for many years (see Wild et al., 2002), yet the uptake of the stormwater management train approach remains limited and challenging in many settings.

Figures 14 a-p. NBS for urban water: sustainable drainage (SUDS) & blue-green infrastructure

Biofilter, Rotterdam.
NAIAD Project.
Image: Field Factors

Streetside rain garden, Parklaan maaibaar, UNALAB Project

Rain garden - detention, Sheffield
Image: Tom Wild



Green roofs, Malmo Biodivercity.
Green Surge Project

Green roof, Paris.
Regreen Project.
Image: ARB idF

Green roof, Valladolid,
UrbanGreenUp Project

Detention – brownfield site Zurich.
Image: Tom Wild

Retention basins, Hefveld.
UNALAB Project

TRE 'alluvial meadow' constructed wetland, UNALAB Project

Green Walls, Bogota, Sao Paulo and Sheffield
Images: Tom Wild, CONEXUS Project

Zurich's Bachekoncept: city river daylighting. Image: Tom Wild

Detention wetland: former steel works
Tom Wild, VALUE project

Urban river deculverting
Image: Tom Wild,
SEEDS project

BOX 20. The ERDF projects Grey to Green & Grey to Green II in Sheffield, England benefited from synergetic funding streams enabled by the Sustainable Urban Development instrument (ERDF Article 7) to implement NBS within a wider Strategy supporting green and inclusive development. In this example of innovative integration, local priorities to promote brownfield regeneration were linked with ESIF Priority Axes 4 and 5[14], generating investment worth >£7.5m. The scheme involved creating attractive GI assets combining NBS together with harder 'grey' investments such as cycling routes. According to H2020 NATURVATION this represents the UK's largest retrofit SUDS project.

Figures 15 a-e. ERDF Grey to Green project, Sheffield, England. Photos: Sheffield City Council

2014

2015

2016

2014

2016

[14] ESIF Priority Axis 4: Supporting the shift towards a low carbon economy; Priority Axis 5: Promoting climate change adaptation, risk prevention and management.

Particular barriers purported to limit the scope for using NBS to control urban sources of water pollution relate to the costs of land-take and the issue of adoption and maintenance. However, many studies do not properly consider the wider co-benefits of NBS for urban water management, or their integration within wider GI networks (Ashley et al., 2011). The economic benefits of SUDS and other blue-green infrastructure (BGI) may include increases in house prices (Netusil et al., 2014; Zhou et al., 2014). Apostolaki et al. (2005) used social research methods to understand the wider implications for local communities of stormwater management practices. Public sector investments in urban water NBS such as SUDS and deculverting projects can deliver social, environmental economic and benefits, including in weak or failing urban property markets where such interventions may increase overall development viability (Wild et al., 2011; 2017).

BOX 21. H2020 POWER: Mukhtarov et al. (2019) concluded that collaborative learning, while essential for legitimacy of a policy innovation, is not sufficient for policy change and a national legal and institutional framework is required to incentivise SUDS practices.

An area where research evidence is lacking relates to performance and characteristics of plants and soils for pollution control and water storage in different contexts under different maintenance regimes, and the impact of climate change on those qualities, choices and supply chains. This links closely with the EC's Circular Economy ambitions. A particular knowledge gap exists around the relationship between the use of plants and landscapes for water management as compared with biodiversity and with their aesthetic qualities in different contexts (e.g. Kabisch et al., 2016b; Fernandes & Guiomar, 2018; Hoyle et al., 2017).

A further knowledge gap concerns the relationships between perceptions and measurement of water quality, access to water, aesthetics and classifications schemes. The links between people's support for water quality improvements, and the inclusion or exclusion of aesthetic measures of the quality of water bodies is an area that has not been properly addressed by policy-relevant research and innovation projects.

BOX 22. The H2020 NATURE4CITIES project uses 'dynamic assessment methodology' to evaluate NBS impacts at different spatial scales across an entire project lifecycle, by generating surrogate data. The simplified urban assessment tool is used to integrate hydrological and diffuse pollution data with other environmental outcome indicators.

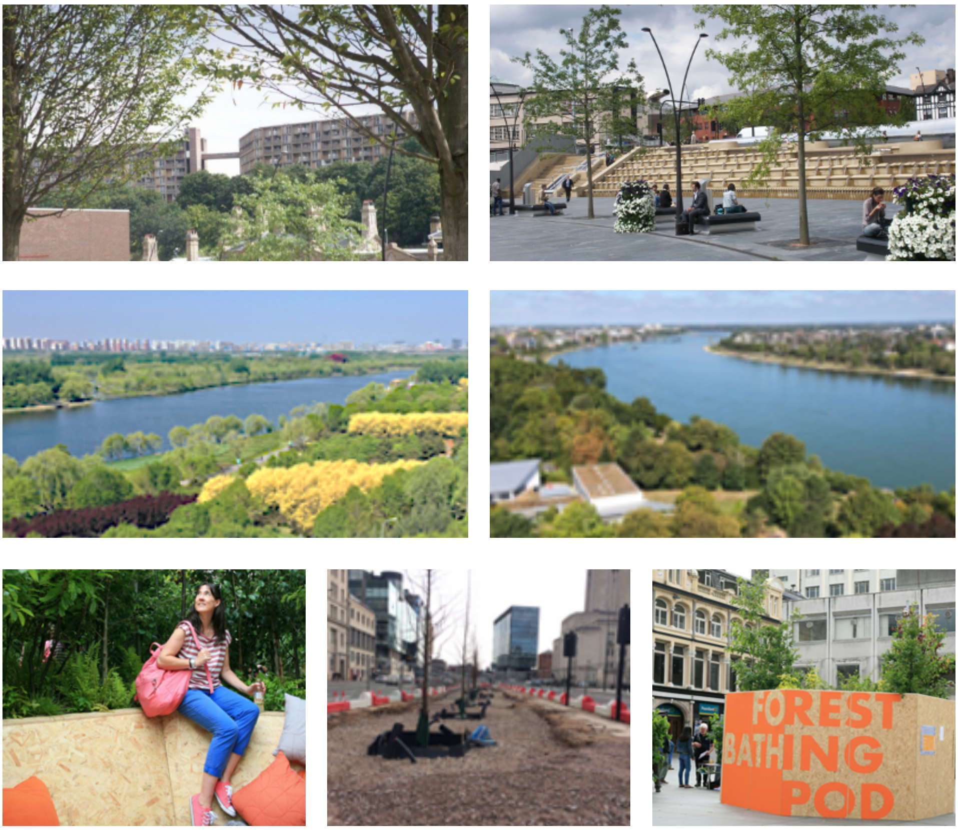
Few studies have addressed the control of priority hazardous substances (PHS) in surface water runoff using NBS. Waste water treatment works (WWTWs) are not specifically designed for the removal of contaminants of emerging concern (CECs), which pose serious hazards to human health and ecosystems (Krzeminski et al., 2019). Unknowns remain as regards the performance of NBS in treating/ removing sewage-derived and waterborne bacteria, micropollutants, viruses and plastics (e.g. Clary et al. (2017a); Gorito et al. (2017); Krzeminski et al. (2019)). Oral et al. (2020) emphasise that plant-associated NBS play a crucial role in removing different CECs, with the key removal pathways being the uptake by plants, microbial degradation, adsorption and sedimentation. Notably, the Joint Programming Initiatives (JPIs) on Water, Oceans and Antimicrobial Resistance (AMR) recently announced a joint transnational call for projects in the area of pollutants and pathogens present in water resources.

BOX 23. In FP6 ScorePP, Scholes et al. (2008) investigated the control of PHS such as arsenic, cyanides and herbicides in surface water runoff. Rainwater GI interventions consistently outperformed conventional grey infrastructures in removing PHS. Their work showed that NBS such as SUDS and constructed wetlands are effective in removing contaminants of emerging concern (CECs) discharged in effluents of wastewater treatment systems - vegetation in these NBS can directly uptake and translocate CEC, which, can be transformed to less toxic compounds during metabolisation in plants.

The WFD objective to achieve good surface water chemical status means that concentrations of pollutants cannot exceed standards established in the EQSD within water environments. The significant decrease in water bodies that are of unknown chemical status (from 39% to 16%; EC, 2019a) does indicate that the monitoring (spatially, substances and frequency) and status assessment methods have improved overall. However, 16% still represents significant non-compliance, meaning that much remains to be done to improve both the uptake and development of monitoring protocols. It is also possible that PHS and other contaminants in stormwater and diffuse pollution sources are responsible as causes of downgrading in water bodies where point sources of pollution have been addressed, yet environmental outcomes remain poor. An important gap exists between and actual implementation of pilots and mainstreamed strategies across EU Member States. This is an area for policy development requiring careful consideration of the relationships between strands of research, practice and policy. Living labs approach pursued through the H2020 NBS projects could usefully be applied to hasten progress towards the Zero Pollution ambition for toxin-free environments.

BOX 24. In H2020 CLEARING HOUSE, benefits of urban forest solutions, including stormwater management improvements, are being explored jointly between cities in EU and China. The opportunities presented by urban woodlands and forestry are summarised in Salbitano et al. (2016). The potential of 'massive tree planting' (Bastin et al., 2019) has recently received much attention. As well as providing useful options for sustainable drainage (see H2020 URBAN GREENUP), urban forests contribute to climate change mitigation through carbon sequestration and storage. Pérez-Soba et al. (2016) describe methods for establishing carbon sequestration, and the capacity of forests to remove carbon from the atmosphere (stored in live and dead biomass and in soils). Urban forestry offers many advantages, not least in offering alternatives to using agricultural land for non-food producing purposes, which may be problematic in low and middle income countries (see Pritchard & Brockington, 2019).

Figures 16 a-f. 'Tree SUDS' & urban forest NBS.
Images: a&b, Tom Wild; c&d Clearing House; e,f&g: UrbanGreenUP.



5.4.3. Agricultural pollution, drainage and soil erosion in rural catchments

The EEA State of Water Report 2018 notes that agricultural production is also a major source of diffuse pollution. Although average levels of orthophosphates and nitrates concentrations declined significantly in European rivers between 1992 and 2015, it highlights that in the 2nd RBMPs Member States identified that diffuse pollution affects 38% of surface water bodies. Agriculture is the main pressure causing failure to achieve good chemical status in groundwater, due to nitrates and pesticides pollution: diffuse pollution sources affect 35% of groundwater bodies by area, and diffuse pollution from agriculture is the major pressure causing poor chemical status, affecting 29% of groundwater bodies by area (EEA, 2018). Nitrogen pollution is particularly important for water quality (Mateo-Sagasta et al., 2017). As highlighted in WEF (2020), five direct drivers of nature loss have accelerated since 1970 - globally, around 115 million tonnes of mineral nitrogen fertilizers are applied to croplands each year; a fifth of these nitrogen inputs accumulate in soils and biomass, while 35% enter the oceans (Mateo-Sagasta et al., 2017). Nitrates affect over 18 % of the area of groundwater bodies (EEA, 2018).

BOX 25. OPPLA provides a synopsis of long-term research, including work funded through FP7 OPENNESS undertaken by CEH at Loch Leven in Scotland (May & Spears, 2012), exploring practical management options to enhance freshwater ecology, including the use of buffer strips and other catchment-based approaches to reduce erosion and to prevent diffuse pollution. “The enormous improvement in water quality at Loch Leven over the last 25 years, and the associated improvements in food and habitat for wildlife, provide a world leading example of what can be achieved when scientific evidence is used to underpin restoration and management activities." Dr Linda May, CEH.

The scale of the diffuse pollution problem was comprehensively explained in Campbell et al. (2005); its relative importance has increased over time as point-source problems have been removed. Source control measures employing NBS such as rural Best Management Practices (BMPs) depend on sustainable and economically viable approaches to agricultural land management. Diffuse pollution from agricultural sources is also closely linked with erosion and soil quality, and progress has been limited since the May 2014 decision to withdraw the proposal for a European Soil Framework Directive. Soil erosion and diffuse pollution exert wide and adverse social and economic impacts well beyond local environmental degradation, for instance through the costly siltation of reservoirs (Kovacs, 2012) and resulting requirements for additional treatment of drinking water. According to Natural England, between 2004 and 2009, water companies in England spent £189 million removing nitrates and £92 million removing pesticides from water supplies in order to meet drinking water standards (National Audit Office, 2010).

BOX 26. In H2020 AQUANES, Zawadzka et al. (2019) found that members of the public welcomed combined natural and engineered water systems including riverbank filtration, constructed wetlands and soil-based managed aquifer recharge, as compared with their engineered equivalents. They assessed a range of ecosystem services and report that the interventions performed favourably in terms of carbon storage, pollination, water retention, sediment retention, nutrient retention and habitat connectivity for biodiversity.

Furthermore, modifications to hydro-morphology are a significant issue in rural as well as urban areas. The main drivers of the physical alterations reported for water bodies in the second RBMPs are flood protection and agriculture (EEA, 2018). For almost 60% of the waterbodies affected by hydro-morphological pressures, these are caused by physical alterations in the channel, bed, riparian zone or shore. Earlier, only 10% of the supplementary measures for diffuse pollution sources and hydro-morphology had been completed by 2012 - 75% were ongoing and 15% had not yet started (EC, 2015b). There are many ways that NBS can be used to mitigate more harmful water quality impacts of agricultural activity, across the whole cause-effect spectrum of drivers, pressures, states, impacts and responses. From a strategic, EU-wide perspective, key drivers can be considered as a function of the trends in land use and associated ecosystem services (Maes et al., 2015).

BOX 27. H2020 NATURVATION: NBS can range from measures to prevent flooding (e.g. NWRM, dyke relocation, re-naturing rivers, buffering areas, restoration of wetlands, woodlands, floodplain, remeandering, de-poldering, set back of estuarine defences, maintaining dunes, beaches and salt marshes) to responding to droughts and erosion in rural areas using sustainable agricultural practices and irrigation systems, reforestation, rainfall water management, torrents and river management (Bulkeley, 2017).

Quoting Newell-Price et al. (2011), McGonigle et al. (2012) noted that "there is a growing body of evidence on the cost-effectiveness of measures to tackle diffuse water pollution". Vinten et al. (2004) appraised rural best management practices (BMPs) in Scotland including NBS for diffuse pollution control and biodiversity enhancement. They conclude that effective measures include nutrient budgeting, retention of winter stubble, headland subsoiling, use of buffer strips, restricting livestock access to water and constructed wetlands. Frost et al. (2004) identified both diffuse pollution risks and options for habitat conservation and enhancement; financial data were also gathered to determine the current sources of farm income, which was used to devise a possible agri-environment grant scheme to aid the implementation of the whole farm plans. Cuttle et al. (2007) reviewed a range of similar measures to reduce diffuse water pollution from agriculture, describing in detail the costs and technical effectiveness of each measure. Clary et al.'s (2017b) review of the performance of 26 types of BMPs concludes that these interventions provide significant reductions in pollutant loading from agricultural land.

The EEA's (2018) European Waters Assessment highlighted that "During the implementation of the first RBMPs, there were several examples of Member States strengthening action to reduce nutrient pollution from agriculture". Member States are implementing different kinds of measures, e.g. using farm-level nutrient planning, setting fertiliser standards (e.g. timing), using appropriate tillage, using nitrogen-fixing and catch crops, setting aside buffer strips and using crop rotation.

BOX 28. Funded by LIFE+ EKOROB Izydorczyk et al. (2019) report on the impacts of diffuse pollution reduction programmes in the Pilica catchment and Sulejów Reservoir in Poland. Cooperation between water managers, interdisciplinary researchers and stakeholders catalysed capacity-building and public participation. Spatially-targeted mitigation measures were identified, based on the modelling results and following discussion of the measures by stakeholders. They concluded that eco-hydrological NBS should be used complementarily to good agricultural practices, which in this case has contributed to a faster achievement of good ecological status of water bodies.

In terms of forestry and woodland, measures to meet WFD objectives can be integrated with adaptation strategies and measures to promote climate change mitigation, using NBS interventions such as catchment restoration measures (Nisbet et al., 2011) and floodplain forests (Dixon et al., 2016). Nagabhatla et al. (2018) provide an overview of the role of forests as NBS for ensuring water security. Knickel & Marechal (2018) reviewed rural NBS projects and actions that are less dependent upon regulations and publicly funded policy measures alongside the agri-environment schemes under Common Agricultural Policy (CAP) Pillar 2. Together these funds and initiatives provide financial incentives to farmers to adopt more sustainable practices or to maintain agro-ecosystems that might otherwise be lost.

BOX 29. H2020 NAIAD is developing methods for the monetary valuation of water regulating services. Hérivaux et al. (2019) note that econometric approaches can be applied to assess water quality benefits provided by forests using water bills data. They highlight Fiquepron et al.'s (2013) findings that on average, 1 ha of afforestation would generate a saving for French domestic water users of ca. 22€/user/year (2004 prices) due to improved water quality, and Abildtrup et al.'s (2013) reports of household water bills reductions ranging from 99 to 138 €/ha/year (2008 values) of newly created forest.

The EU Water Regulation Fitness Check (EC, 2019b) emphasises the importance of the issue of cross-compliance between WFD outcomes and the two Pillars of the CAP. As regards the first pillar, which includes payments for environmentally friendly farming and mechanisms to stabilise farm revenues, by delivering public goods not normally paid for by the markets - instruments have been put in place to ensure coherence of the CAP's payments with environmental legislation. Several of these cross-compliance requirements have direct and indirect impacts on water quality and water quantity protection. However, it is also noted that a 2016 European Court Auditors report shows that the effects of cross compliance are also limited by the fact that not all farmers supported by the CAP have to comply with cross-compliance (approximately 68% have to comply; some e.g. organic farmers are not required to meet these requirements). The rate of non-compliance for the statutory management requirement stemming from the Nitrates Directive is 10%.

BOX 30. H2020 PEGASUS investigates environmental and economic impacts of organic farming, e.g. the 'Skylark' organic farmers cooperative's work in the Dommel area of Midden Brabant in the Netherlands (Westerlink & van Doorn, 2016; Hart et al., 2017). This brings together stakeholders including food processing industries, the public, and the Water Board, to address intractable challenges - including efforts to address water quality problems that have been hard to resolve through normal policy measures. The region faces some of the most intensive agriculture in Europe, exerting significant pressures on natural resources. Environmental regulation and agri-environmental schemes were deemed insufficient to resolve these problems. Plans for exchanging water quality measures with land leases are being used to develop riparian buffer strips and reed fields in lower areas to improve water quality, in return for land elsewhere instead of through financial subsidies (the Water Board owns 180 ha of land in the region).

Martin-Ortega et al. (2014) review the evidence on relationships between peatland degradation and poor water quality. They report that while it is difficult to establish cause-and-effect relationships between peat restoration and WFD outcomes, in river catchments with significant peat degradation there is evidence of poor water quality leading to failure to achieve good ecological status. Bonn et al. (2016) provide an overview of valuation studies of peatland restoration. Glenk et al. (2018) report that benefits exceed cost in appraisals of previous and future public investments in peatland restoration. ONS (2019) investigated values for the restoration of 100% of UK's peatlands, with costs estimated at between £8 billion and £22 billion, yet with the benefits (including carbon sequestration) of having 55% of peatland in good status being ~ £45 billion to £51 billion over a 100 year-period.

BOX 31. H2020 NAIAD features a case study of the Moors for the Future project in the Peak District, UK. Its LIFE+ MOORLIFE scheme restored 893 ha of damaged peatland to self-sustaining, active blanket bog. NAIAD researchers reported improved water quality and flood risk management delivered through (1) recovery of the natural vegetation, creation of erosion detention barriers and tree planting; 2) changes in agricultural practices; and (3) changes in land use and infrastructure to reduce diffuse pollution.

Mitsch & Gosselink (2000) highlight a 'trap' of assigning economic value to natural ecosystems such as wetlands (and, by extension, NBS) in that if short-term economic analyses are made it will always be possible to find more profitable (e.g. commercial) land-uses. They highlight that: wetlands are multiple-value systems; relationships between wetland area and marginal value is complex; and their most valuable 'products' are public amenities.

BOX 32. H2020 PHUSICOS investigates the use of NBS to reduce hydro-meteorological risks in rural and mountainous regions. The project will deliver a 'receded green barrier' on the River Gausa, at Jorekstad near Lillehammer, Norway. Built using only natural and local materials, the barrier will contribute to water quality improvements to meet WFD objectives (Oen et al., 2019). Due to diffuse pollution impacts from agricultural land runoff, the river has only moderate ecological status as regards total phosphorous, and a poor state in terms of total nitrogen. By creating a wetland and setting back the flood barrier the scheme is intended to prevent plastics and other substances from entering the river, as well as reducing nitrogen and phosphorous runoff, and mitigating against the loss of fish habitat and spawning areas.

The literature on natural water retention measures (NWRM) and natural flood-risk management (NFM) is growing rapidly. Ngai et al. (2017) provide a comprehensive review of relevant evidence provided through the UK Environment Agency's 'Working With Natural Processes' project on flood and coastal erosion management. This provides compelling evidence for the benefits and co-benefits of NBS covering river and floodplain management, woodland management, runoff management, and coastal and estuary management. It also highlights important research needs, including: knowledge on 'leaky barriers' and catchment restoration improvement measures; monitoring of the geomorphic, hydraulic and ecological effects of river restoration (such as daylighting culverted rivers); and better understanding of the functioning of floodplains during extreme events. Despite this evidence on the impacts and co-benefits of NBS, action to implement and upscale ecosystem-based approaches in rural catchments has been pitifully slow throughout most of Europe. This points to the need for a different approach, and the co-production methods trialled in H2020 offer significant scope to be adapted in rural environments.

Figures 17 a-f. Rural and peri-urban NBS including catchment management and rural BMPs

(a) Catchment restoration, Gudbrandsdalen, Norway (PHUSICOS)

b) Constructed wetland (OPERANDUM)

(c-f) Peatland grip-blocking & buffer strips, Peak District UK, MoorLIFE / SEEDS. Images: Tom Wild

5.4.4. Hydro-morphology and the restoration of modified waterbodies

According to Albert et al. (2019), many of the ecosystem services lost through river straightening, bank modification and agricultural intensification can probably be brought back through river restoration, and thus river landscapes provide a particularly useful setting to make use of NBS. The EEA State of Water Report 2018 highlights that river and floodplain restoration measures involving NBS may be used to address hydro-morphological pressures, which have the most widespread impacts on surface water bodies (40% of all surface water bodies affected). Fish populations are particularly susceptible to such pressures via the impacts of interruptions in longitudinal continuity, riverbank constructions, large flow fluctuations, and water abstraction (EEA, 2018). Hydro-morphological changes also exert other important adverse impacts on flood risk management, erosion, nutrient pollution and amenity.

The WFD requires the assessment of waterbody status and prospects for achieving 'Good Ecological Potential' (GEP) of HMWBs resulting from physical alterations by human activity, which substantially change hydro-geomorphological character (Borja & Elliot, 2007).

Hanley & Black (2006) noted that “the WFD recognizes the need to accommodate social and economic considerations, so HMWBs may be designated where achievement of the Directive's objectives may result in disproportionate costs”, and that “significantly, the HMWB designations themselves are uncertain, because the ecological status assessments on which they depend are not certain”. They conclude that for Scotland as a whole, implementation of the WFD is predicted to result in positive net benefits.

BOX 33. In FP7 WISER Verdonschot et al. (2013) assessed restoration measures comparatively across the four major categories of rivers, lakes, transitional and coastal waters. Also analysing WISER data, Borja et al. (2013) provided assessments for the biological quality elements (phytoplankton, macroalgae-seagrasses, macro-invertebrates and fish) requiring evaluation, validating existing indicators and developing new indices. They report that indices respond differently to specific pressures, and each comes with challenges in defining reference conditions against which future changes may be judged.

Heavily modified river systems and their multiple human impacts pose considerable challenges for assessment of their ecological status (de Leeuw et al., 2007). The ‘one-out-all-out’ approach means that many nations are far from achieving good status even though almost all member states accomplished WFD formal implementation of PoMs: in Germany, 82% of all surface water bodies were exempted from good ecological status requirements under Article 4 of the WFD (Richter et al., 2013). Although the development of HMWB assessment methods has been a transparent process and has resulted in improved and more standardised tools, the process has been more time consuming, and methods are more complex, than originally expected (Hering et al., 2010).

BOX 34. The H2020 NAIAD project team reports that Spain’s National River Restoration Strategy delivers WFD and Floods Directive outcomes, with the objective to implement a series of actions meant to initiate a ‘process of change in the management of river systems’, which will lead to an enhancement of the ecological status of rivers, while gradually increasing the involvement of the public (Rica et al., 2017). H2020 AMBER provides international guidance on adaptive management of the operation of dams and barriers in European rivers to achieve more efficient restoration of stream connectivity and to address river fragmentation impacts.

The modification of river bank structures, reconnection of backwaters or floodplains, and restoration of wetlands are among the most common NBS measures applied to achieve hydro-morphological improvements (EEA, 2018), incorporating specific techniques such as removal of bank fixation, re-meandering or widening, tree planting and preserving riparian zones. It can also include the re-introduction of animals, that can modify the environment in ways that suit human beings as well as improving their own habitat - for instance, in rural environments Eurasian beaver activity increases water storage, attenuates flow and mitigates diffuse pollution from intensively-managed grasslands (Puttock et al., 2017).

BOX 35. The H2020 URBINAT project includes cases of several sustainable drainage demonstrator projects including the daylighting and restoration of culverted watercourses. In 2015 at the Asprela-Quinta de Lamas Park, a brook was deculverted and restored, creating opportunities for active recreation, making connections between different social groups, and building a closer relationship between the University and watercourse (Farinha-Marques & Lameira, 2017). The scheme retains a large volumes of runoff from the watershed, with rain water falling in the park being managed on site through infiltration and storage using a system of retention basis, prior to discharge to the deculverted watercourse. The watercourse section was designed to retain water volumes from a 1 in 50 year recurrence storm event.

Other river restoration measures including daylighting (deculverting), which entails opening up piped and buried rivers and restoring them to more natural conditions (Wild et al., 2011) to deliver a wide range of social, economic and environmental benefits. Daylighting has been called the most 'radical' expression of river restoration (Pinkham, 2000) and is primarily, though not exclusively, an urban endeavour or intervention (Wild et al., 2019).

BOX 36. Wild et al. (2019) report on two daylighting case studies in Sheffield, UK, funded by Interreg IVB SEEDS, the Environment Agency and Sheffield City Council (one city-centre project, one rural headwaters scheme). Costs data were synthesised and analysed, using information from an international database of self-reported cases. Urban deculverting schemes cost USD 21k on average compared with USD 6k for suburban and rural sites (2017 prices); daylighting yielded differing, valuable benefits in each setting.

Figures 18 a-d. Porter Brook daylighting Peak District, Sheffield, UK. Images: Tom Wild

2011

2012

2013

2020

Kail & Wolter (2011) note a lack of knowledge on the effect of restoration measures and a specific gap around how to enhance the ecological state of HMWBs. Post-project evaluation and outcome reporting of river restoration projects remains rare (Bernhardt et al., 2005) and thus it is often unclear whether the goals of restoration schemes are achieved (Palmer et al., 2010). In contrast to the degradation effects, biotic responses to restoration are less well-known and not easily predicted (Hering et al., 2010). Surrogates such as riparian tree cover, woody debris presence and sediment transport are thus increasingly used, often at catchment scales by employing technological advances e.g. remote sensing data (see Bizzi et al., 2016).

BOX 37. FP7 REFORM developed a hierarchical framework of river behaviour (RHF) to support water management. It provided a methodology to complement official WFD guidelines for hydro-morphological surveys (CEN2004) addressing process-form interactions over spatial scales from catchments down to sub-reach levels - e.g. geomorphic and hydraulic units (Gurnell et al., 2015). Bizzi et al. (2016) showed that many of the proposed RHF assessment indicators can be derived using remote surveying sources and existing methods, and that Member States already have sufficient data to begin incorporating them into WFD assessments and monitoring of hydro-morphology.

According to Palmer et al. (2014) "ecosystem restoration was originally founded upon recovering ecosystems using wildlands as a reference state… more recently there has been interest in shifting to restoring… the benefits that natural systems can provide to humans". Piégay et al. (2020) go further in suggesting that fluvial systems are now 'socio-ecological hybrids' and that human (river) constructions can be perceived as potentially valuable novel ecosystems.

BOX 38. The H2020 project RECONECT project will make available water quality and quantity data on the performance of the Niederneunforn river restoration project in the Thur River Basin, Switzerland (completed in 2002 through the RECORD project). The Thur River in NE Switzerland was channelised in the 1890s. Since 1993, several river sections were widened to allow the formation of alternating gravel bars colonised by pioneer vegetation and to increase hydrological connectivity between the main channel and floodplain. Habitat enhancement created by the restoration has provided a broader range of ecological niches and improved aquatic and riparian biodiversity - however, more erosion has taken place leading to lost riparian forest; strategic balancing between erosion control and rehabilitation is needed (Schirmer et al., 2014).

Figures 19 a & b. Niederneunforn River. Photos: BHAteam, Frauenfeld

Bledsoe et al. (2016) provides a useful summary of research and development needs relating to river restoration techniques including (1) bed and bank stabilisation; (2) riparian buffers; (3) in-stream enhancement; (4) floodplain reconnection and (5) other restoration practices including dam removal and land-use management. This review provides specific areas for future investigation to better understand the performance or river restoration techniques for the removal and retention of nutrients, sediments and catchment management of stormwater.

BOX 39. FP7 DESSIN researchers report that large-scale river restoration "pays off" (Gerner et al., 2018). In this ecosystem service valuation case, a wide range of benefits delivered by the €5.3 bn Emscher river restoration programme were analysed. Market values of the restoration schemes were calculated totalling €21 million every year along with non-market values of €109 million per year. Benefits analysed included: self-purification and retention of N, P and C; maintenance of nursery populations and habitats; alignment with other infrastructures; reduced risk of flooding; opportunities for biking and recreational boating; appreciation of restored stream sections; and opportunities for understanding, communication and education.

5.4.5. Wider relationships with cohesion, regeneration, health & wellbeing

Quoting de Vries et al. (2003), Faivre et al. (2017) note that access to natural recreational areas may help prevent socio-economic inequality from leading to health inequality. Van den Bosch & Ode Sang's (2017) systematic review of reviews addresses pathways and services, as well as defined health outcome benefits of NBS, including stress reduction, heat reduction, increased physical activity, noise reduction and decreased obesity (however this did not cover air pollution).

Drawing on a range of studies, Kabisch et al. (2016a) report that urban blue spaces can also help to reduce air pollution levels and heat (depending on their context, management and planning), as well as protecting individuals from diseases related to harmful environmental exposures e.g. reduced infections from contaminated drinking water. Their findings support a beneficial impact of the use of green and blue spaces and residential surrounding greenness on behavioural development and ADHD in children, in line with Amoly et al.'s (2014) evidence of beneficial associations between use of blue spaces and wellbeing outcomes. Similarly, Twohig-Bennett & Jones (2018) meta-analysis of health outcomes of greenspace exposure showed statistically significant reductions in blood pressure, salivary cortisol, heart rate, diabetes, cardiovascular mortality. They conclude that although systematic review results were limited by poor study quality and high levels of heterogeneity, greenspace and street greenery may form part of a multi-faceted approach to improve a wide range of health outcomes.

BOX 40. In FP7 GREEN SURGE Kabisch et al. (2016a) found that a lower percentage of natural area cover was correlated with deficits in children's viso-motoric development, and that areas with lower natural area per capita had significantly higher values of childhood obesity. They note that while resources are limited and may prohibit extensive re-greening, 'upstream' prevention of health problems may still be achieved using innovative solutions e.g. opening currently private spaces or refurbishing less well maintained urban greyfields, whilst being mindful to mitigate against eco-gentrification.

Following work on the FP7 PHENOTYPE project, Lawrence et al. (2019) stress that much research relating to health benefits of outdoor natural environments have followed oversimplified linear cause–effect models, whilst neglecting interaction between key variables and feedback loops between different components. Ossola et al. (2018) also highlight that many projects fail to capture the complexity of service provision mediated by interactions between people and ecological structures. These results point to important areas for future research and innovation.

BOX 41. H2020 CONEXUS includes pilot interventions with local schools and NGOs to investigate the health, wellbeing and educational opportunities of urban NBS, such as constructing green walls to mitigate pollution impacts of traffic congestion (in Buenos Aires). Contributions of and benefits to young people of NBS represent important opportunities for implementation of the UN Sustainable Development Goals. In particular, challenges should be stressed around youth unemployment in market failure areas. According to the World Bank/ILO (2015) ~1/2 of all young people in the world are unemployed or underemployed, and this situation is likely to get worse (BA, 2019). However, surprisingly little evidence exists about young people's perspectives of global challenges and solutions, and the potential responses that can be pursued using NBS.

Zhou et al. (2014) estimate the marginal willingness to pay for proximity to urban blue-green spaces of various types. They evaluated the performance of the four strategies (laissez-faire, pipe enlargement, local infiltration, open urban drainage systems). All adaption strategies investigated were found to be economically beneficial relative to the laissez-faire alternative. The largest gain was found for the open SUDS solutions, with a considerable increase in estimated net present value, when taking into account the additional environmental amenity benefits. They conclude that a budget-oriented cost-benefit analysis approach alone is insufficient to support through decision-making, as it will miss the potential additional non-market services (negative and positive) achievable using urban water NBS.

Incorporating attractive NBS can play a significant role in encouraging regeneration in locations where a surfeit of empty properties or stalled development mean that the private sector may be unlikely to take the lead in implementing NBS to deliver ecosystem services (Wild et al., 2017). Since such schemes can deliver multiple co-benefits for a wide range of citizens and users, investment in NBS by governments at the national and local level is justifiable as an effective way to stimulate inclusive regeneration. These findings build on the results of earlier EU projects investigating the economic impacts of landscape quality improvements within regeneration programmes such as in the Ruhr, Germany (Mielke, 2008). Similarly, Netusil et al. (2014) report property sale price increases with tree canopy coverage; they suggest that the value of street trees outweigh their maintenance costs, and can help overcome the market failure identified in Donovan & Butry (2010).

Figures 20 a & b. Blue green infrastructure: NBS for urban river corridor regeneration 'Streets' and 'Parks' redevelopment options (images: URSULA project team)

NBS have the potential to increase the connectivity between existing, modified and new ecosystems, as well as offering important opportunities for social innovation to restore and rehabilitate ecosystems within cities and at the urban-rural interface. Examples of interventions that can deliver such win-wins include healthy green corridors, providing both routes to employment centres for rural communities, and greater more inclusive access to the countryside for urban populations.

BOX 42. H2020 URBINAT is co-creating 'healthy green corridor NBS' with citizens in seven EU cities. At Porto in Portugal, this process includes the active participation of parish organizations and initiatives to involve local actors, resources and talents in designing and creating interventions. Also in Portugal, a €75m national programme has been commissioned to restore 5,000 km of freshwater streams, using NBS to help prevent forest fires, soil erosion, droughts and flooding, and to improve biodiversity and water quality. Within this programme, 1,000km length of rivers have already been restored (costing €11.5m) and a further 5,000km are targeted for restoration (at a cost of €75m). The Minister of the Environment has highlighted that such NBS are part of the national effort to reduce emissions and mitigate against climate change, and that NBS living-labs in 16 different municipalities helped bring together civil engineers, local authorities, the forestry sector and other businesses. Riverside 'parkways' connecting urban and rural communities represent important opportunities to achieve synergies between ecosystem restoration and social integration.

While the H2020 cross-cutting sustainable cities initiatives made real inroads to low carbon development for motorised forms of transport, arguably, much less attention was placed on the potential to increase walking and cycling. By combining urban mobility plans with BGI interventions, significant potential exists to integrate NBS within healthy blue-green 'parkways'. These river corridor regeneration approaches represent important opportunities for Just Transitions, facilitating both ecosystem restoration and social integration. Non-motorised transport options offer two-way benefits for productivity of reduced congestion on the one hand and increased activity and wellbeing on the other, both contributing to GVA (multi-modal mobility e.g. INTERREGEUROPE).

5.5. BUSINESS MODELS & FINANCING (WATER QUALITY & WATERBODY CONDITIONS)

NBS-type interventions for urban water quality management, such as green roofs, can achieve cost savings due to reduced stormwater flows and CSO spills, outperforming hard infrastructure storage tanks on cost grounds, whilst improving urban environmental quality and other valuable co-benefits (Montalto et al., 2007; Engstrom et al., 2018; Davis & Naumann, 2017; CIRIA, 2015). Similarly, in rural communities, integrated valuations of NBS for water purification and flood protection show they can outperform grey infrastructure alternatives, at a similar cost, whilst providing additional benefits such as wildlife habitat and recreational opportunities (Liquette et al., 2016).

The economic benefits of SUDS and other NBS may include increases in property values, or willingness to pay for housing and NBS maintenance costs, attributable to views and access to these green assets (Mell et al., 2013; Netusil et al., 2014; Zhou et al., 2014). Public sector investments in urban water NBS can deliver significant benefits in weak or failing urban property markets where such interventions may increase overall development viability (Wild et al., 2017), in line with the results of earlier EU projects investigating the economic benefits of GI (e.g. Mielke, 2008).

The daylighting or deculverting of underground, piped rivers can also deliver significant economic outcomes (Wild et al., 2011) - the City of Zurich is estimated to have significantly reduced WWTW costs by removing stream flows from the sewer network, such that each litre per second of river flows diverted from the sewer saved the city around 5000 Swiss Francs per year in treatment costs. Using this source data, Broadhead et al. (2013) estimate that for a typical WWTW (Esholt, Bradford), removing the 16% of baseflow from captured streams and springs would deliver a cost saving of between £2 million to £7 million. Wild et al. (2019) reported that urban deculverting schemes cost USD 21k on average, compared with USD 6k for rural and suburban schemes. Based on multilevel hedonic pricing models, Kang & Cervero (2009) concluded that daylighting of the Cheong Gye Cheon in Seoul, Korea delivered net benefits to both residential and non-residential land markets.

The FP7 DESSIN case study of the Aarhus River reported that the benefits of opening the river and the associated water quality improvements are estimated to be €120 million, while the costs of enabling infrastructure including real-time control systems was ~€47 million, with an operating cost ~€600k/year. This valuation is limited to the benefit of opening the river in city centre, and does not include the social benefits of water quality improvements to the lake, the harbour and the upper river section between the lake and the central city (Jensen et al., 2014).

BOX 43. NBS investments can yield considerable economic returns at both regional and local scales, and an important challenge is to understand how government organisations can best target the location of green investments to maximise socio-economic benefits (after Gellinck, 2013). This applies to networked infrastructures such as green cycling routes, as well as NBS for water management at the catchment scale. In H2020 NAIAD economic valuations of flood storage and ecosystem services are being undertaken for proposed NBS in Romania as part of Lower Danube Green Corridor scheme, including wetlands, canopy cover, floodplains, waterbodies and soil. NAIAD results show that "the impact of individual small wetlands can be lost in the noise and uncertainty of data and processes associated with catchment modelling" (Burke et al., 2018).

A new model Eco:actuary for insurance industry valuation is being piloted by NAIAD, coupling elements of WaterWorld and Co$tingNature (Mulligan et al., 2019; see also OPPLA). This entails mapping absolute insurable asset value per pixel in GIS-based tools, which provide an interface for experts in economic valuation to enter economic and insurance values, and can be used to map economic asset values of (collective) NBS investments. The NAIAD project team stresses the following key issues: the location of NBS interventions within catchments is critical; these NBS interventions should not be considered in isolation from each other; and the sum of all interventions upstream of assets is critically important (Burke et al., 2020).

At the macro-scale, Hanley & Black (2006) concluded that implementing the WFD in Scotland was likely to generate benefits in excess of costs, with a central benefit to cost ratio of 1.69:1. Noting that the "benefits are likely to be considerably greater than those identified in their study, because many gaps in the benefit assessment exist", they relate this to the option to designate water bodies as HMWB and associated exemptions from the requirement for good ecological status. Whilst this may reduce WFD implementation costs for some EU Member States, it also has significant implications for social and environmental justice (Fairburn et al., 2005; 2009) and eco-gentrification (Haase, 2017; Kabisch et al., 2016a), about which important questions remain.

BOX 44. ONS (2019) investigated values for the restoration of 100% of the UK's peatlands, with costs estimated at between £8 billion and £22 billion, yet with the benefits (including carbon sequestration) of having 55% of peatland in good status being between £45 billion and £51 billion over a 100 year-period.

5.6. INNOVATIVE GOVERNANCE (WATER QUALITY & WATERBODY CONDITIONS)

Hindering factors to successful implementation of the WFD include national (and local) governance frameworks (EC, 2019c), and the possibilities and models for public participation in the WFD River Basin Management Plans (RBMPs). Appropriate scales for, and means of, engagement in water management (in line with Article 14) remain an important area for innovation. H2020 NBS projects are exploring and demonstrating innovative ways to bring together strategic priorities such as biodiversity and climate change resilience with participatory actions to promote sustainable water management in rural and urban environments. The living lab model of NBS demonstrators can add significant value and bring a new dimension to the development of more nuanced water policy in Europe. Online resources usefully complement and scale-up the impact of these local demonstration projects. At a strategic level this includes the resources available via CIRCABC, as well as platforms such as OPPLA that promote wider access to NBS evidence.

BOX 45. OPPLA reports that H2020 AQUACROSS governance innovations linked with policy-making and implementation were used to better understand the interactions and feedback processes between society and ecosystems that influence long-term restoration outcomes. The Lake Ringsjön Rönne å Catchment case in Kattegat, Sweden provides insights into how collaborations can be achieved across different water governance levels, sectors and geographical regions, to improve catchment management outcomes. Similarly H2020 PEGASUS case studies on cross-compliance in agriculture, demonstrate how WFD implementation may be integrated with other EU legislative requirements.

URBACT, the European Territorial Cooperation programme that aims to foster sustainable integrated urban development in cities across Europe, also serves to promote innovative water management and governance models. Its good practices resource showcases around 100 cases from 25 countries, documenting efforts to achieve more sustainable urban development. An easy-to-search database provides city practitioners with a snapshot of the practice, why it works, the context, and who to contact for more details. An example promoting better WFD and climate change resilience outcomes is the urban waterways strategy and action plan reported here, providing practicable information on how cities can use collaborative planning and partnership approaches to integrate bottom-up local citizens' engagement with strategic water priorities. Similarly, the FP7 PREPARED project provides important lessons on reflexive adaptation for resilient water services (Westling et al., 2019).

These examples play an important role to meet the recommendations of the EC's water management Fitness Check (EC, 2019b), to promote programmes of measures that will help to achieve the WFD 2027 environmental objectives. They show how the EC is working with Member States to improve implementation at the lowest possible cost, e.g. by sharing best practices on GI and cost reduction of pollutants at source. However, collaborative learning and participation alone are in themselves insufficient to improve waterbody conditions and to meet current sustainable water management challenges, including diffuse pollution and hydro-morphological impacts. For instance, Mukhtarov et al. (2019) draw on their work in the H2020 POWER project to show how collaborative learning, while essential for legitimacy of a policy innovation, is not sufficient for policy change and a national legal and institutional framework is required to incentivise SUDS uptake.

Furthermore, EU NBS projects help to address a specific challenge in the successful implementation of water legislation, around retrofitting to solve existing problems. Achieving good waterbody status depends not only on mitigating new and emerging pressures, but also requires faster progress to retrofit appropriate measures to solve issues such as diffuse pollution and hydro-morphological impacts (EC, 2019b). Inspiring and engaging examples include Urban GreenUp's pop-up forest, GROWGREEN's vertical gardens in Valencia schools, the UrbanbyNature global programme for urban nature pioneers, and Naturvation's Innovation Pathways. H2020 NBS projects are grappling with global societal issues, and working collaboratively across sectors and regions to find innovative solutions, covering a wide spectrum of social, technical, economic, environmental and political measures.

5.7. POLICY RECOMMENDATIONS AND KNOWLEDGE GAPS (WATER MANAGEMENT)

This section provides a summary of policy recommendations and knowledge gaps, firstly regarding water management challenges, and secondly, taking a broader perspective on NBS research, innovation and implementation.

5.7.1. Recommendations and gaps specific to NBS for water management

Several H2020 projects are investigating the water management benefits of NBS as regards pollution control and reduced flashiness of stormwater flows in urban and rural areas. Very few tend to incorporate integrated monitoring or modelling of both outcomes, however, and this may prove to be problematic since the two challenges are strongly linked. Important knowledge gaps exist in terms of water quality impacts of catchment-scale habitat degradation and, conversely, WFD benefits of implementing NBS such as peatland restoration (Martin-Ortega et al., 2014). Understanding the impacts of rainfall-runoff from both water quality and quantity perspectives requires investigation of data for specific storms, using methods such as analysis of event mean concentrations to study pollution control benefits of NBS.

Similarly, cooperation on comprehensive catchment flood modelling and monitoring runoff for more frequent heavy storms (expected in many parts of Europe due to climate change) requires new ways to understand how multiple often individually small NBS can combine to deliver collectively significant natural flood management strategies. Integrating these approaches with knowledge coproduction methods in both urban and rural communities would be beneficial. Similarly, international-scale cooperation on data-sharing towards the development of open platforms (e.g. comparable with the US BMP databases) would facilitate more rapid progress.

A topic requiring further investigation that is of particular relevance to water-management NBS, but also of wider interest, involves the performance and characteristics of plants and soils for pollution control and water storage in different contexts under different maintenance regimes. This requires fundamental science and wider academic input on: (a) the impact of climate change on those qualities; (b) the supply chain of materials including plants, soils and substrates; and (c) choices as to what vegetation to plant where, considering relationships between the use of plants and landscapes for water management c.f. aesthetics, c.f. biodiversity (e.g. Kabisch et al., 2016b; Fernandes & Guiomar, 2018; Jorgensen et al., 2017).

Another area where wider expertise would be beneficial involves the activities of the WFD CIS working groups, and in particular the ECOSTAT teams working on hydro-morphology and diffuse pollution. Progress has been made to develop internationally comparable monitoring regimes and scientific underpinnings relating to good ecological status and potential, but a broader range of perspectives beyond the purely technical will be required to shift - from understanding waterbodies - towards facilitating rapid and widespread action to implement measures for achieving good status. Doing so needs insights from social researchers and political sciences as well as those with biological and technical backgrounds. In particular, input may be required from those with expertise in monetary valuation of NBS, to understand data on primarily the economic values-side, but also on the prices- side of NBS cost-benefit analyses, enabling more realistic comparisons with hard-engineered approaches especially at finer scales and in specific development contexts (e.g. Wild et al., 2017; Keeler et al., 2019; Albert et al., 2019). The challenges and opportunities therein are also linked with earlier decisions not to include aesthetics as a WFD indicator for waterbody status, in contrast with other (predecessor) classification schemes (e.g. see SEPA, 2004).

BOX 46. Policy recommendation: broadening the expertise of WFD working groups

The 2019-2021 Work Programme of the Common Implementation Strategy (CIS), drafted at the time of the water legislation Fitness Check (EC, 2019b) and the WFD assessment report (EC, 2019c) reconvenes several working groups (CIRCABC, 2018). The CIS was tasked with work to investigate the financing of measures and producing a report on good practices for the identification of investment needs and financing sources for the WFD PoMs (CIS, 2018). Furthermore, its Working Groups were required to exchange information and good practices on PoMs, including a library of measures that can be used towards reaching good status. The working group on Flooding refers specifically to the use of NBS in this regard.

The working group ECOSTAT is producing technical guidance, sharing best practices and promoting exchanges of experiences on hydro-morphology. This group has undertaken substantial tasks during previous work programmes (e.g. publishing guidance documents and a mitigation measures library) and new actions have started in the context of the current work programme. This includes further comparison of methods to set Good Ecological Potential, development of a technical document on sediment management, exchange of information and sharing of best practice on methodologies to assess hydro-morphological conditions.

However a broader range of perspectives beyond the purely technical will now be required to shift from understanding waterbodies towards stimulating rapid action to achieve good status. This work would benefit from the input of social and economic research and insights from other fields (e.g. political sciences) as well as biologists and technical experts. In particular, input may be required from those with expertise in understanding the cost effectiveness and public support for ecosystem restoration, and related fields such as monetary valuation of NBS. This additional expertise will be needed if the work programme is to meet its overall aim to improve the implementation and effectiveness of measures to reach good status.

5.7.2. Broader NBS policy recommendations & knowledge gaps

Calls for proposals on NBS have been extremely popular with city and regional governments, which raises some important questions as well as being a success to celebrate. Funding for Innovation Actions around climate and water resilience have been particularly popular and oversubscribed. It is important to consider the reasons why local government authorities would seek to participate in H2020, beyond the obvious benefits of innovating together with partners in strategic international networks. The funding made available by Europe is urgently required to implement NBS in cities. However, EU project funding is not exactly the easiest to administrate, and if local governments are using this income to replace statutory measures or supplement mainstream budgets, then perhaps this indicates that all is not well.

Austerity, in the form of reduced taxes to pay for public goods such as water management services, can be seen as limiting the wide uptake of NBS - even if there is an ambition and capability to use these interventions to deliver a wide range of ecosystem services in cost effective ways. The current (fashionable) focus on blended finance models and investment vehicles (e.g. recycling loans via the private sector to pay for ecosystem services) may need rethinking, particularly in locations where markets are weak or failing (Wild & Henneberry, 2020).

Other useful models to consider might entail longer-term public sector investment employing NBS at appropriately wide scales, to stimulate regeneration and promote wellbeing. Similarly, spatial planning, regulation, land value capture and tax incentives may prove to be more successful in stimulating more rapid uptake of NBS than relying solely on private sector investment. Nevertheless the market has a key role to play. Europe currently has a genuine advantage in growing knowledge economy around NBS but will not retain this lead for long without further investment, refinement and harvesting of cooperation potentials. H2020 NBS programmes would benefit from further development of knowledge exchange and 'impact-accelerator' type approaches involving the private sector. This could entail using new methods of co-production, bringing experts and research users together with stakeholders and knowledge brokers. For instance, international cooperation on SME development in NBS could be enabled through the targeted use of exchanges, secondments and placements, facilitated by more flexible project structures and financing mechanisms. Doing so could support trade within and beyond the EU in line with the original vision for the NBS 'Reference Framework', which seems to have rather dropped off the agenda.

However, as yet the underpinnings for these kinds of impacts are not fully in place. At present, the generation of programme-level data on NBS communities of practice remains underdeveloped, and this is an important gap that should be addressed. Projects may be required to collate and report data about participation of different sectors in events, training and continual professional development activity. This would support strategic understanding and development of capacity in the emerging professional field of NBS implementation.

Such capacity-building intelligence and activity needs facilitating at both the EC-level and at the scale of individual projects. This strategic goal of professionalisation could also be supported through a tailored programme of complementary activities, for instance by developing specific strands in awards programmes and skills development initiatives (e.g. Eurostars, Marie Skłodowska-Curie Actions and Innovative Training Networks), and through the use of structured thematic calls.

A particular area of concern linked with skills and professional training relates to youth unemployment, made worse by the recent economic shocks linked with COVID-19. The lack of opportunities for young people was already a systemic problem and a significant threat to cohesion in Europe prior to the pandemic, with around half of all young people in the world unemployed or underemployed and the situation "likely to get worse" (British Academy, 2019).

In the coming years, all sectors of society will need to do much more to create a wider range of chances for skills development and professional advancement. Doing so will require patience and time due to the inevitable impacts in education and personal development associated with such a huge disruption, and its adverse effects on mental health and wellbeing. It is estimated that one billion young people will enter the labour market between 2015 and 2025, and that only 400 million of these young people will be likely to find jobs in the formal economy (World Bank, 2015). Careful consideration is required in the conception, framing and development of programmes that can bring in perspectives of young people to global sustainable development challenges. This should involve people from a wide range of socio-economic backgrounds, directly including youth themselves, to shape programmes for NBS skills development using this particular lens on societal challenges.

Nature-based Solutions for Flood Mitigation and Coastal Resilience

Zoran Vojinovic

6. NBS FOR FLOOD MITIGATION AND COASTAL RESILIENCE

6.1. INTRODUCTION

Out of all types of natural disasters those disasters that are related to hydro-meteorological phenomena (e.g. floods, storm surges, hurricanes/typhoons, among others) have shown the fastest rate of increase in their frequency and intensity (e.g., Guha-Sapir et al., 2016). With growing trends of climate change and sea level rise, the challenges concerning flood management are likely to become even more demanding. Adaptation to climate change provides an opportunity to improve our current practices by introducing NBS which, if implemented properly, can also provide multiple co-benefits[1] besides flood risk reduction.

The term NBS appeared in 2008 and it is considered to be an “umbrella concept” for a range of different terms. Ruangpan et al., (2020) identified several different terms that relate to NBS in the context of hydro-meteorological risk reduction. These are: low-impact developments (LIDs) which appeared in 1977, best management practices (BMPs) appeared in 1980, water-sensitive urban design (WSUD) appeared in 1994, green infrastructure (GI) appeared in 1995, sustainable urban drainage systems (SUDS) appeared in 2001, ecosystem-based adaptation (EbA) appeared in 2009, ecosystem-based disaster risk reduction (Eco-DRR) appeared in 2010 and blue–green infrastructure (BGI) appeared in 2013.

These terms are mainly related to small-scale NBS which represent solutions applied at the urban or local scale, for instance at the level of individual buildings, streets or roofs (e.g., porous pavements, green roofs, rain gardens, vegetated swales, rainwater harvesting, bioretention, infiltration trenches, Figure 21a). Large-scale NBS are solutions which are applied in rural and coastal areas, river basins and/or at the regional scale (e.g., large retention basins, lakes, flood plains, wetlands, forests, beach nourishment, mangroves, coral reefs, etc., Figure 21b).

The review of literature to date confirms a large gap between the research efforts concerning small- and large-scale NBS with small-scale NBS receiving far greater attention. This could be due to several reasons. One reason is that small-scale NBS are very attractive for storm water management and regeneration of urban areas. They are also less complex and their benefits and co-benefits can be observed relatively soon after their implementation. Also, research experiments concerning small-scale technologies are more conveniently installed in labs. Furthermore, the costs concerning their pilot implementations, operation and maintenance, at both individual and public levels, are also more affordable.

Further to the above, there is growing evidence that small-scale NBS can provide multiple benefits to urban areas and ecosystems (e.g., flood mitigation, enhancement of biodiversity, creation of new jobs and promotion of human well-being). For example, Eckart et al., (2017) reviewed the performance and implementation of LIDs (which can be regarded as small-scale NBS) and provided a summary of the knowledge of LID as a promising stormwater management technique and climate change mitigation measure.

Compared with traditional urban stormwater management practices, LID alternatives have the function of returning the runoff using natural processes (Stovin et al., 2010; 2015; 2017). Qin et al., (2013) analysed the performance of an urban drainage system in an urbanizing area of Shenzhen, China, where some LID practices (e.g., swales, permeable pavements and green roofs) are designed to reduce urban flooding. It was reported that such measures are more effective in flood reduction for shorter storm events. In addition, Dietz (2007) reported that a green roof can reduce 60–70% of stormwater volume when compared to a conventional roof. Alfredo et al. (2010) found that green roofs can delay and prolong the roof discharge and reduce its peak rate by 30–78% compared to a standard roof surface. Keesstra et al. (2018) and Bengtsson et al. (2005) also provided evidence of green roof water quantity performance benefits.

Figures 21 a & b. Examples of small (a) and large-scale NBS (b)

(a) Green roof in Malmo, Sweden. The main purpose is to reduce the stormwater runoff and mitigate flood risk. A green roof can also provide other economical, ecological and social benefits, i.e., co-benefits (e.g., purify the air, reduce the ambient and indoor temperature, save energy and enhance biodiversity in the city).
(Photo: Alison Duffy)

(b) The lake Egå Engsø in the bay of Aarhus, Denmark - one of the H2020 RECONECT demonstration sites. The purpose of establishing the wetland "Egå Engsø" is to reduce the nitrogen supply to Aarhus Bay, to improve the natural conditions in Egådalen (the valley of Egå) and to reduce the flood risk from the river Egå. The wetland also enhances the area's recreational value. (Photo: Casper Tybjerg, TTF)

Other NBS have also been shown to attenuate runoff volumes. Abbott and Comino-Mateos (2003) measured the outflow from a car park with a permeable pavement system and found that on average, only 22.5% of runoff leaves the system during a storm, and that a 2-hour storm event takes two days to drain out of the system. Fassman & Blackbourn (2010), in turn, found that the peak flow from a permeable pavement underdrain is less flashy and tends to show less variation overall than that from asphalt surface during storms. Chapman & Horner (2010) reported that a street-side bioretention facility in Washington can achieve 26–52% of runoff retention for certain rainfall events.

A good example of an initiative that combines several GI flood protection measures at the urban scale (i.e., small-scale NBS) is the Sponge City Programme (SCP) in China (Chan et al., 2018). The measures implemented within this initiative aim to provide multiple opportunities for integration between stormwater management and flood control, landscape architecture and building design, eco-hydrology and land-use planning as well as social and environmental well-being.

In the UK, flood risk mitigating remains a key priority for the Government and in the draft London Environment Strategy, the Mayor encouraged the use of SUDS as a way to manage stormwater in view of their co-benefits that they can also deliver (e.g., improved air and water quality, greater biodiversity and reduced noise). The UK Construction Industry Research and Information Association (CIRIA) developed the SUDS construction manual as a guidance document for the construction of SUDS to support those designing, specifying and constructing such measures and helping them to understand and avoid common pitfalls (CIRIA, 2015).

With regards to large-scale NBS, the Dutch 'Room for the River' Programme represents a paradigm case for implementation of such measures. It consisted of 39 local projects which combine different types of measures such as floodplain lowering, dike relocation, groyne lowering, summer bed deepening, water storage, bypasses and floodways, high-water channels, removal of hydraulic obstacles, and dike strengthening (Klijn et al., 2013). The benefits of that programme were not observed only with respect to flood risk reduction but also in relation to enhanced opportunities for recreation, habitat and biodiversity enhancement (Klijn et al., 2013).

The European Environment Agency reports that 70 to 90% of Europe's floodplain areas are degraded due to the human intervention into the river bodies. Restoration of floodplains through implementation of NBS would not only ensure protection from flood damages further downstream but it would also prevent erosion, replenish groundwater aquifers, improve soil health and restore biodiversity, which are all necessary for healthy and resilient ecosystems.

Another example of large-scale NBS implementation is the Laojie River restoration project in Taoyuan in Taiwan. The focus of this work was on changing the channelised, culverted watercourses into an accessible GI corridor for the public (Chou, 2016). This work was inspired by the Cheonggyecheon Stream restoration project in South Korea which represents yet another example of a successful large-scale NBS project, which provides effective flood prevention, ecological, recreational and aesthetic improvements. The Cheonggyecheon Stream restoration project also brought numerous economic benefits where development capital has been invested and property prices have doubled (CABE, 2011).

In terms of the other types of large-scale NBS, Acreman & Holden (2013) show how wetlands play an important role in the hydrological cycle, influencing groundwater recharge, low flows, evaporation and floods. Prior to that, a major review of scientific literature reporting hydrological functions of wetlands was undertaken by Bullock & Acreman (2003). They reviewed the evidence for whether wetlands reduce flooding and found that about 80% of studies suggested that floodplain wetlands reduced flooding while other studies indicated that some upland wetlands increased flooding. Field observations have shown that vegetation cover can affect the velocity of water flowing across wetlands and hence flood generation (Holden et al., 2007). Using plot-scale measurements, Holden et al. (2008) showed that *Sphagnum* spp. have ability to slow the flow of water across peat surfaces when compared to sedge-covered surfaces and bare peat surfaces (for an order of magnitude slower). Keeler et al., (2019) reports that vegetation with high roughness is the most effective at slowing overland flow of stormwater runoff. Species root depth and structure influence infiltration and retention of nutrients, and leaf nutrient content and phenology affect the amount and timing of nutrient export to stormwater systems.

Typical examples of coastal NBS are mangrove, mudflats, dunes, beach nourishment and coral reefs and they all require certain conditions to be effective. Balke et al., (2011) reported that mangrove restoration is not very effective in environments that do not have the right range of tidal exposure, salinity, and nutrients required for mangrove establishment. Similarly mudflats are also reported to be more effective in low wave energy environments, whilst dunes and beaches and coral reefs are typically more effective in higher energy environments (Pontee et al., 2016). Other typical examples of coastal NBS are beach nourishment interventions which often rely on coastal processes to redistribute the sediment. The Netherlands has adopted a relatively new approach known as 'building with nature' which makes the use of the dynamics of the natural environment and provides opportunities for natural processes. It represents a collection of coastal NBS interventions including sand engines, oyster reefs and wave-attenuating forests (De Vriend et al., 2015).

In view of the numerous benefits and co-benefits of NBS, it can be concluded that such measures have strong potential to contribute towards meeting objectives of policy documents addressed in this document, namely Floods Directive, Action Plan on the Sendai Framework for Disaster Risk Reduction 2015-2030 and EU Strategy on Adaptation to Climate Change. This document aims to provide an overview of the results from EU-funded NBS projects in support of these policy instruments and to identify the gaps for future R&I investments. Examples of such support used in the review process include provision of theoretical knowledge and practical evidence, development of knowledge base platforms and portals, provision of materials for capacity development, and development of standards and guidelines for implementation, monitoring and evaluation of NBS interventions.

The following section provides an overview of the three EU policy instruments.

6.2. OVERVIEW OF MAIN FLOOD-RELATED POLICIES AND THEIR CONNECTION WITH NBS

This section addresses the three EU policy instruments and their connection with NBS. Regarding the use of terminology, it can be noted that NBS and its related terms are not equally used in all three documents. Terms such as 'green (and blue) infrastructure', 'ecosystem-based management/approach' and NBS are explicitly mentioned in two documents (i.e., EU Action Plan on the Sendai Framework for Disaster Risk Reduction 2015-2030 and EU Strategy on Adaptation to Climate Change). The Floods Directive does not provide explicit reference to any of these concepts, since it was published prior to the date of appearance of these terms.

6.2.1. Floods Directive

The Floods Directive (FD), originally proposed in 2006 and formally published in the Official Journal of the EU in November 2007 (EU, 2007; Directive 2007/60/EC), envisions the following:

- Preliminary flood risk assessment: the first step of the implementation cycle, to identify areas where significant flood risks exist or are reasonably foreseeable in the future.

- Flood risk maps: the second step is to: make flood hazard maps and flood risk maps available to the public; support the process to prioritise; justify and target investments and develop sustainable policies and strategies; support flood risk management plans; and spatial planning and emergency plans.

- Flood risk management plans (FRMPs): the third step - these need to be developed and implemented at river basin/sub-basin level to reduce and manage the flood risk. The plans need to include the analysis and assessment of flood risk, definition of the level of protection, and identification and implementation of sustainable measures by applying the principle of solidarity in relation to transboundary flood risk governance. In this case, large-scale NBS can play an important role in promoting the *solidarity principle*[15] as they require strategies that address land management across transboundary landscapes or jurisdictions, involving a great variety of actors and stakeholders.

The FD was as an important step towards harmonising and establishing a common flood management framework for EU member states. As such, it established a set of formal rules with regards to flood risk management at both EU and at the national level. Taking the present day's view, despite some shortcomings, this Directive still provides a good foundation for those countries that may be less advanced in their flood risk mitigation practices.

However, for those countries that are more advanced in flood risk management, their existing practices have gone beyond objectives to promote flood risk management

[15] 'Solidarity" is defined as one's act to support members of a particular community to which one believes to belong (Bayertz 1999). The Floods Directive requires from Member States to pursue an integrated and co-ordinated approach for selection of flood protection measures based on the principle of solidarity and shared responsibility. Although the principle is in itself straightforward, the precise meaning of solidarity is unclear in the context of upstream–downstream practices of transboundary flood risk management. It is necessary to more specifically define the meaning of solidarity for future cross-border adaptation governance (Van Eerd et al., 2015a).

actions. For example, in the Netherlands, the effect of the FD on the national policy has been minimal (see for example, van Eerd et al., 2015b). Priest et al., (2016) suggest that the Directive could be strengthened by requiring more intensive cooperation and providing the competent authorities in international river basin districts with more power. A number of shortcomings associated with this document are discussed in Tsakiris et al., (2009) and Eleftheriadou et al., (2015).

BOX 47. The FP7 RISC-KIT project final report states that coastal authorities need to assess levels of impact and risk for their coastal zones, implementing Disaster Risk Reduction (DRR) measures to prevent or mitigate coastal disasters. To facilitate risk reduction, the UNISDR (2015) formulated the Sendai Framework and the EU has issued the FD. The project findings suggest that both frameworks do not provide sufficient details to address coastal hazards and impact issues adequately and they also do not provide appropriate tools. The RISC-KIT project has developed a set of tools to support these demands.

There are several aspects where possible future FD revisions address NBS and/or their related concepts and foster their implementation across the European Union. As a starting point, there should be a clear reference to the available evidence of NBS in relation to different types of floods. The range of flood reduction measures, even though the present version of the FD document makes the reference to 'multi-purpose measure that can be used for different forms of sustainable human activities (e.g. flood risk management, ecology, inland navigation or hydropower)', should be broaden to more explicitly and specifically discuss applicability and effectiveness of small- and large-scale NBS for different types of floods, contexts and situations.

Updates to the FD should also acknowledge recent innovations. Implementation of small-scale interventions has several advantages when compared to traditional grey infrastructure. However, their effectiveness in mitigating effects from large and extreme events is rather limited which in turn may necessitate combinations with large-scale interventions. Also, large-scale NBS could play important role in flood risk mitigation for transboundary river basins (e.g., INTERREG DANUBE FLOODPLAIN Project Report on Possible Restoration Approaches).

Taking the above into account, it can be concluded that while the current FD provides a good foundation for those Member States that are not so advanced in flood risk reduction practices, there is significant potential to explicitly address NBS and support creation of new and optimise performance of existing interventions individually and in their hybrid combinations with grey infrastructure. Considering that across the EU, most flood risk management plans for the first implementation cycle are either complete, or nearing completion (with the second cycle of flood risk management plans being due in 2021) an assessment of the extent to which different types of NBS were considered by different Member States would prove invaluable. Furthermore, future implementation cycles may facilitate the uptake of NBS by learning lessons about the removal of barriers to the uptake of NBS, and detailed consideration of how Member States have achieved this would be beneficial.

6.2.2. EU Action Plan on the Sendai Framework for Disaster Risk Reduction

The Third UN World Conference on Disaster Risk Reduction was held in Sendai (Japan) in 2015. At that event, the United Nations Member States agreed and adopted the Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030, UNISDR (2015). That framework represents the main guiding instrument for Disaster Risk Management (DRM) and it highlights the sense of urgency for "substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries".

The implementation of the Sendai Framework represents an opportunity for EU to take forward its DRM agenda which is reflected in the EU Action Plan on the SFDRR (EC, 2016). This document is planned to be updated in 2020 and the new version will guide EU implementation of the SFDRR for the next 10 years. It identifies four priority areas: understanding risk, strengthening disaster risk governance to manage disaster risks, investing in disaster risk reduction and resilience, and enhancing disaster preparedness for effective response and to 'Build Back Better'.

BOX 48. NBS have the potential to improve the condition and resilience of ecosystems in urban, rural and wilderness areas and as such, they can contribute to implementing the SFDRR 2015–2030, while also contributing to achieving other policy objectives - from biodiversity conservation to climate change adaptation and mitigation (Faivre et al., 2018). The EC has been active in engaging the research community to better address the related knowledge and technology gaps through its Research and Innovation strategy and Framework Programmes. Fostering green growth and promoting implementation of such approaches is a priority of the EU Action Plan on the SFDRR 2015-2030, which sets the basis for a disaster-risk-informed policy making at EU level. The Union Civil Protection Mechanism which includes requirements to carry out risk assessments, is an important instrument in this respect, covering also other forms of natural and manmade risks than floods.

The SFDRR represents an essential step towards global political awareness for climate change adaptation and the use of NBS for disaster risk reduction and resilience. It has been indicated that for some of the EU countries the local practices still remain oriented towards the emergency response phase of the disaster cycle (prevention, preparedness, response, recovery, restoration), without particular reference to the goals of the framework (see for example, Goniewicz & Burkle, 2019).

BOX 49. H2020 NAIAD investigates how the (re)insurance industry could support the risk reduction measures including NBS, in line with the Sendai Framework. The project results illustrate how the (re)insurance industry is gaining a better understanding of hazards and mitigation, in turn opening the possibility of new arrangements like natural insurance schemes and evidence-based assessment of avoided damage costs from green protective measures, in Europe and beyond (see also Marchal et al., 2019). The results provide valuable references for the APSFDRR and the EU Climate Change Adaptation Strategy to emphasise the importance of insurance as a non-structural flood protection measure. The CASCADE project funded by DG ECHO (Directorate General for Civil Protection and Humanitarian Aid) addresses climate change risk management at the local authority level in the Baltic Sea Region (BSR). It supports the implementation of the UN's SFDRR in the BSR. The project points to the lack of political support for DRR at the international level. This is important to highlight since some of the countries in the region are very active in providing various forms of support for DRR to the countries that are the most vulnerable and exposed to severe natural threats. The project's findings to date suggest the lack of political support to the Sendai implementation, which makes coordination and organisation of the work more challenging. This project has particular relevance for the APSFDRR as it aims to increase the knowledge and capacity of civil protection experts and city planners by developing training courses in DRR.

The APSFDRR document makes explicit reference to NBS and other related terms such as GI and ecosystem-based approaches. The relevant sections acknowledge the benefits from such interventions in a more general context of disaster resilience. However, what is not sufficiently addressed are the concrete actions and how or in what way they should (or can) be taken to support these interventions.

When mentioned, the reference to these interventions is primarily given in the context of Key Area 3 - Promoting EU risk informed investments (Sendai Priority 3 "Investing in disaster risk reduction for resilience") with some reference made to the NBS-evidence brought by the current H2020 Framework Programme for Research and Innovation as well as the previous Framework Programmes and actions. Also, the numerous benefits and co-benefits of NBS for DRR are not explicitly mentioned.

Furthermore, there is no explicit mentioning of the financing mechanisms and business models that can be used to support NBS implementation. Overall, although the APSFDRR document encourages NBS interventions (either implicitly or explicitly) there should be more explicit and stronger support for NBS in all four key areas of Sendai priorities. For example, in relation to (i) understanding risk - NBS has a role towards risk mitigation opportunities; (ii) DRR governance - NBS provide opportunities in bringing multiple stakeholders together - thereby strengthening governance and management of disaster risk; (iii) investing in DRR - NBS provide an opportunity in cost-effective investments; and (iv) building back better - NBS offer multiple benefits that provide greater societal benefits.

6.2.3. EU Strategy on Adaptation to Climate Change (SACC)

The EU Strategy on Adaptation to Climate Change (SACC) was adopted in April 2013 (EC, 2013) and aims to increase the resilience across the EU's territory by enhancing the preparedness and capacity of all government levels to respond to the impacts of climate change. As part of the EU Green Deal, this strategy is currently under review and will be updated in 2021. The Strategy should be fulfilled through the implementation of eight Actions in three thematic areas:

1. Promoting action by Member States

- Action 1. Encourage all Member States to adopt comprehensive adaptation strategies (Member State strategies);
- Action 2. Provide LIFE funding to support capacity building and step up adaptation action in Europe (LIFE);
- Action 3. Introduce adaptation in the Covenant of Mayors framework (Covenant of Mayors);

2. Better informed decision making

- Action 4. Bridge the knowledge gap (Knowledge gap);
- Action 5. Further develop Climate-ADAPT as the 'one-stop shop' for adaptation information in Europe (Climate-ADAPT);

3. Climate-proofing EU action by promoting adaptation in key vulnerable sectors

- Action 6. Facilitate the climate-proofing of the Common Agricultural Policy, the Cohesion Policy16, and the Common Fisheries Policy (ESIF/CAP/CFP);
- Action 7. Ensure more resilient infrastructure (Infrastructure); and
- Action 8. Promote insurance and other financial products for resilient investment and business decisions (Insurance and finance).

The EU is integrating adaptation into several of its own policies and financial programmes. Currently, most EU Member States have adopted the EU Adaptation Strategy. A considerable amount of knowledge and information concerning climate adaptation measures, monitoring and modelling practices as well as region-specific issues and challenges has been generated through various EU research programmes (e.g., H2020, FP7, INTERREG, COST Actions, LIFE) and can be accessed through the European Climate-ADAPT platform.

Many projects financed by the EU have addressed topics such as floods, sea level rise, droughts or intense heat. Future work should give more attention to specific vulnerabilities of certain communities and multiple risks that are posing threats to different regions around Europe. The new EU Adaptation Strategy should scale-up NBS implementation and stimulate related business opportunities, based on reliable and standardised data and evidence. Additional research and innovation actions at EU level that promote systemic NBS and their benefits in cities and territories are planned with the aim to improve the implementation capacity and evidence base for NBS and developing corresponding future markets (Faivre et al., 2017).

BOX 50. OPPLA – the repository of NBS reports that the water retention reservoir in Podutik in Ljubljana (Slovenia) has two main objectives: 1) to improve and maintain a good ecological status of the nearby watercourses and, 2) to mitigate floods in the nearby settlements of the city of Ljubljana, to help deliver FD and Water Framework Directive (WFD) objectives. The existing reservoir was redesigned into a multifunctional flood reservoir that provides a broad range of ecosystem services through the iwfdntegration of NBS. The city of Ljubljana and the FP7 project TURAS co-funded the project.

Out of the three policy instruments reviewed, the SACC document provides more prominent support to NBS and other related terms and concepts, making explicit reference to some of their benefits and co-benefits and pointing to the knowledge base platforms and evidence obtained from the current and previous programmes and actions. Therefore, when comparing the level of support in all three documents, the support for NBS in the SACC document can be characterised as 'strong explicit support'; for the APSFDRR it can be characterised as 'medium explicit support'; and for the FD that support is rather 'low' and/or implicit.

In short, NBS offer invaluable strategic and practical options towards meeting objectives of the three EU policy instruments and the level of support to their implementation should be more explicitly stated in future versions of these documents. They can benefit from direct incorporation of NBS in the following ways:

- Contributing towards the global climate change agenda - NBS are increasingly recognised as an essential aspect in the development of climate change mitigation and adaptation strategies. Since the three policy instruments addressed in this document aim at reducing disaster risk and increasing resilience to climate change, by setting up a more quantifiable and measurable targets in relation to NBS will ensure that the collective measures have the capacity to strengthen the global response.

- The need for holistic planning - All three policy documents advocate the need for holistic planning and development of measures with multiple benefits. By its nature, the process of implementing NBS necessitates holistic thinking and working that pulls together a range of sectors and disciplines. Combined with traditional grey infrastructure these measures offer city managers, planners, water and environmental authorities with a variety of hybrid solutions that can be selected in relation to desired benefits and trade-offs.

- Sustainability and multi-functionality - One of the key characteristics of NBS is their capacity to provide multiple functions which go beyond mere stormwater runoff control or flood risk reduction for which they may have been originally designed. They can also offer a number of benefits to multiple sectors. Hence, by incorporating NBS into the existing policy documents the goal of achieving sustainable and multifunctional solutions, which is clearly advocated in all three documents, can be realised.

- Active stakeholder participation and collaborative governance – Successful implementation of NBS projects requires active stakeholder participation and collaborative governance at different levels. In case of large-scale interventions their implementation will also require trust in the local and regional governments. As such, they also provide an opportunity to strengthen inter-governmental as well as transboundary relationships and promote the solidarity principle. This can in turn foster the possibilities for their implementation and operationalisation at the EU and National levels. Schleyer et al., (2015) argue that factors such as the degree of bindingness, policy obligations and impacts on multi-level governance as well as the types of interventions targeted, type of support, etc. are diverse and of crucial importance in this context.

6.3. CONTRIBUTION OF EU-FUNDED PROJECTS TO FLOOD-RELATED POLICIES

In the context of the present work the findings from several EU projects on NBS (H2020, FP7, INTERREG, COST Actions and LIFE) were reviewed in relation to their potential to contribute towards the above EU policy instruments and to identify the gaps for future R&I investments (for the list of reviewed projects see Annex 1). Three key large-scale NBS demonstration projects concerning hydro-meteorological risk reduction are currently under implementation within the H2020 programme. These are OPERANDUM, PHUSICOS and RECONECT. In all three projects, the ongoing work relating to real-time monitoring and control, business models, standardisation, NBS performance indicators, evaluation frameworks and social acceptance will all significantly contribute to the policies described above.

In its demonstration and upscaling activities, RECONECT draws on a network of Demonstrator and Collaborator schemes covering diverse local conditions, geographic characteristics, institutional/governance structures and social/cultural settings, to successfully upscale NBS throughout Europe and internationally.

RECONECT has the potential to contribute to FD, APSFDRR and SACC with respect to novel risk assessment approaches and methodologies for selection and evaluation of NBS. For example, Alves et al. (2019) proposed a method that can be used to analyse the trade-offs between different benefits and co-benefits of NBS. The same work also provides evidence that evaluation of flood reduction measures can be significantly different when the co-benefits are not included in the analysis. The RECONECT case area in Thailand applies an evaluation framework proposed by Watkin et al. (2019) to quantify the benefits and co-benefits of implemented NBS.

Figure 22. Creation of an additional space controlled by portable flood gates that sit under the road and within the flood plain in the Ijssel region in the Netherlands (H2020 RECONECT project demonstration site). This site is part of the "Room for the River" programme. It aims to provide flood protection, enhance the landscape and improve environmental conditions in the areas surrounding the Netherlands' rivers. (Photo: Zoran Vojinovic)

OPERANDUM combines ten NBS sites, or Open-Air Laboratories (OALs) covering a wide range of hazards, with different levels of climate projections, land use, socio-economic characterization, existing monitoring activities and NBS acceptance (see Figures 23 & 24). Renaud et al. (2019) provide a systematic literature review on vulnerability and risk assessment frameworks addressing natural hazards focusing on those used for assessing NBS. Their contribution to EU policy implementation, and particularly FD, relate to the selection and use of indicators for measuring social and ecological vulnerability to natural hazards, and how these indicators can be used to assess the success of NBS in reducing vulnerability and risk.

Figure 23. Po Valley (Panaro river, Comacchio valleys, Reno, Emilia Romagna coastal area), Italy, is part of the OALs within the H2020 OPERANDUM Project. The delta of Po river represents the transition between the river and the sea with differing hydraulic, morphological and biological characteristics. The NBS addresses multiple hazards such as floods, droughts, coastal erosion and storm surges and it also presents economic and biodiversity values. (Photo: Michael Loupis)

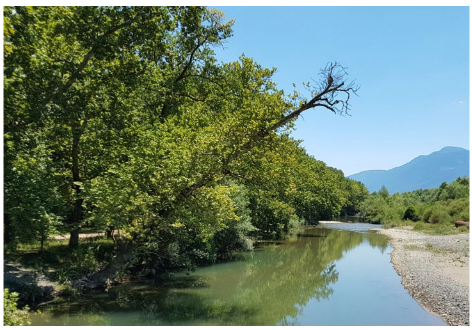


Figure 24. Sterea Ellada region is a location for OPERANDUM's Greek OAL NBS situated in the basin of the Spercheios river. It springs from the mountainous parts of the catchment, mainly from Tymfristos mountain in the West, as well as Vardousia and Oiti mountain ranges in the Southwest and South respectively and it deals with floods and droughts. This NBS also has considerable economic and biodiversity values. (Photo: Michael Loupis)

PHUSICOS focuses on demonstrating the effectiveness of NBS and their ability to reduce the impacts from small, frequent events (extensive risks) in rural mountain landscapes (see Figure 25). Autuori et al. (2019) describe a comprehensive framework to verify the performances of NBS from technical and socioeconomic points of view which plays an important role in the overall evaluation of measures. Further results concerning application and verification of this framework will prove its usefulness and contribution towards the three policy documents with particular reference to hazards and risks in mountainous settings.

Figure 25. The Isar river (Germany) during (left) and after (right) the hydro-morphological restoration. It is one of the main tributaries of the Danube, sources in the Alps, and crosses the Bavarian capital Munich. Heavy rain events in the Alps in the years of 1999, 2005 and 2013 led to major floods. Today's near-natural landscape raises awareness on the usefulness of NBS both for DRR and recreational purposes. (Photo: Zingraff-Hamed)

The NAIAD project combines eight demonstration sites to address questions of insurance value of ecosystems to reduce the human and economic cost of risks associated with water (floods and drought) by developing and testing - with key insurers and municipalities - the concepts, tools, applications and instruments (business models) necessary for its mainstreaming. This work has particular relevance for APSFDRR and SACC to better link insurance and financial services with Cost-Benefit Analysis of flood protection measures. Altamirano & de Rijke (2017) assess the life cycle costs of NBS by providing an overview of the temporal and spatial distribution of costs related to NBS.

The H2020 BRIGAID project deals with the development of innovations for climate adaptation and risk reduction from climate-related disaster impacts in Europe and beyond. It also demonstrates innovative NBS for different situations and contexts. One of them is the use of planting techniques in support of flood risk mitigation and as such it provides value for the FD document. It focuses on two alternative solutions: 1) The installation of Coir Logs at the bottom of the river and 2) planting three levels of vegetation (willow, reed and poplar) at different depths along the river banks to prevent erosion and flooding with natural materials. This

NBS also creates a green corridor, enhancing flora and fauna habitats in the area. This measure is demonstrated along the Erzeni River in Albania. The results from this project provide relevant reference for riverine flood risk assessment and management methods and approaches. Other guidelines and tools that are being developed under this project may also contribute to the development (or fine tuning) of national policy documents for the focus countries.

H2020 RESIN is developing practical and applicable tools to support cities in designing and implementing climate adaptation strategies for their local contexts. The project aims to compare and evaluate the methods that can be used to plan for climate adaptation in order to move towards formal standardisation of adaptation strategies. RESIN public deliverables can be found here. The project provides material to support the implementation of all three policies, particularly in future development of the FD, with respect to vulnerability assessment, standardisation for urban climate adaptation, hazards and risk analysis, and the methods for prioritising adaptation options (e.g. de Jong et al., 2018; Mendizabal & Zorita, 2018).

The main outcome from the PLACARD project is the platform (PLAtform for Climate Adaptation and Risk reDuction) that supports dialogue, knowledge exchange and collaboration between the Climate Change Adaptation (CCA) and Disaster Risk Reduction (DRR) communities. PLACARD produced several policy briefs, visuals and webinars which can be found here and used as a reference for all three policy documents. More specifically, the project's policy brief on NBS recommends that Ecosystem-based approaches must be community-based and consider large spatial scale to minimise trade-offs between communities.

The Smart Mature Resilience (SMR) project aims to deliver resilience management guidelines to support city decision-makers in developing and implementing resilience measures. The project hosted several events, some focusing on sharing experiences and knowledge on how to best co-create NBS. The tools and lessons learnt can contribute to the policies in relation to resilience management guidelines.

H2020 RESCCUE aims to contribute towards improvement in urban resilience: the capability of cities to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage. Although the project does not specifically focus on NBS, its methodologies and tools for assessment of hazards and risk (and particularly risk cascading) can be useful for the FD.

The FP7 RESCUE project addressed impacts of climate-induced floods on stability of existing river flood embankments and looked into the natural reinforcement which can be successfully exploited to strengthen the embankments. In this respect, vegetation is considered as a remedial measure in the sense that it promotes the generation of suction via evapotranspiration (i.e., it is a form of NBS). The work was validated in the case study of the Adige River (Italy) and the results obtained provide a good reference for the FD document.

The FP7 BASE project dealt with sustainable climate change adaptation in Europe. Some of the case study work addressed pluvial, fluvial and coastal types of floods and application of different types of measures including NBS (which are in the project documents referred to as "ecosystem-based" or "green measures"). The results provide a valuable reference for the FD document in relation to uncertainty analysis and efficacy of different measures for different types of floods.

BOX 51. FP7 OPERAS project was a five year EU research project dealing with practical aspects of ecosystem science. It addressed the construction and maintenance of semi-fixed dunes across 15 km of Barcelona's (Spain) urban coastline, effectively representing coastal NBS, with the potential to provide protection from coastal floods and sea-level rise as well as to bring numerous co-benefits to coastal ecosystems. The results provide valuable reference material on coastal management for future development of the FD.

The LAND4FLOOD COST Action aims to address different aspects in relation to Natural Flood Retention on Private Land and to establish a common knowledge base and channels of communication among scientists, regulators, land owners and other stakeholders in the field. Its potential contribution to FD, APSFDRR and SACC is their approach to nature-based flood risk management on private land. The book produced by Hartmann et al. (2019) addresses potentials and experiences of NBS with respect to private and partly public land, and as such, it provides a valuable reference for design and evaluation of NBS of particular value for the new FD.

H2020 UNALAB aims to develop a 'living lab' of NBS sites and provide a robust evidence base to enhance the climate and water resilience of cities. The project also underlines a variety of barriers that prevent wider replication and uptake of these measures. Information that the project aims to produce will be particularly relevant for the SACC's thematic area 2 (Better informed decision making).

FP7 PEARL addressed several aspects of flood risk reduction ranging from the early warning systems technologies to ecosystem-based (NBS) approaches that can be used for multiple-hazards and vulnerability assessment. The work was carried for a number of European and International case studies (see Figure 26). The project brings tools and experiences which are directly relevant for all three policy documents. The project also proposes improved Quantitative Microbial Risk Assessment methods to address public health issues associated with flood waters in urban areas. The work has also addressed application of NBS measures in areas with cultural heritage (e.g., Vojinovic et al., 2016a; Vojinovic et al., 2016b). This could be particularly relevant for FD (e.g. Chapter II, Article 4), APSFDRR (e.g. Key Area 4 - Supporting the development of a holistic disaster risk management approach in relation to cultural heritage), and SACC as well as for other directives for Member States that aim to address cultural heritage requirements.

Figure 26. Coastal flood risk reduction with hybrid measures (i.e., combination of hard engineering and Ecosystem-based approaches) in Taiwan, FP7 PEARL project. (Photo: Zoran Vojinovic)

FAST (Foreshore Assessment using Space Technology) was an EU FP7 Collaborative project which developed down-stream services for the European Earth Observation Programme Copernicus to support cost-effective, nature-based shoreline protection against floods and erosion (see for example, Morris et al., 2015). Wave reduction properties of nature-based shoreline protection against floods were assessed using satellite data and incorporated in a wave and flood model which showed dramatic reduction in extent and depth of flooded area, i.e., the inundated surface without vegetation approximates 340 ha, and only 193 ha with vegetation. The results obtained can serve as a reference to improve FD implementation.

The objective of LIFE SIMETORES project is to address climate change adaptation of urban areas in the Simeto Valley (Italy). The work concerns the inclusion of Blue Green Infrastructure (BGI) into municipal regulations and the construction of six BGIs within the urban territory of the municipalities of Paternò and Ragalna. It can support FD, APSFDRR and SACC through the implementation of BGI measures, being of particular relevance for national policy instruments in Italy and beyond.

The LIFE project GRIN (Promoting urban integration of GReen INfrastructure to improve climate governance in cities) focuses on urban integration of GI for climate governance in cities. It establishes an integrated policy framework to manage, monitor and evaluate Urban Green Areas as a form of BGI, specifically addressing urban climate impacts such as heat waves and heat island effects, stormwater runoff and energy consumption. It provides a useful reference for FD, APSFDRR and SACC in relation to climate change adaptation and mitigation and gives explicit support for the development of national policy instruments in Greece. Their key deliverables provide analyses of the current situation regarding climate change mitigation and adaptation needs (SWOT analysis) in two cities: Amaruson and Heraklion. GRIN's public deliverables can be found here.

FP7 ECONADAPT built the knowledge base on the economics of adaptation to climate change converted into practical information for decision makers for more effective adaptation planning. The project developed a policy-led approach to frame the research and policy analysis focusing on the practical application of adaptation economics, serving as a reference for the SACC (e.g. ECONADAPT, 2015).

RISES-AM was an EU FP7 project which addressed the economy-wide impacts of coastal systems to various types of climatic scenarios (including storm surges and sea level rise). The project developed a set of adaptation pathways for vulnerable coastal systems at regional and global scales, introducing adaptation strategies and innovative solutions to help implement the FD and SACC (see the final report here).

FP7 SECOA studied 17 coastal metropolitan/urban areas of international. national and regional importance, and 26 environmental contrasts/conflicts in 8 countries in Europe and Asia. The outcomes confirmed that climate change is one of the most important challenges for all the coastal areas that have been studied.

In summary, the potential for contribution from R&I projects towards the three policy documents is given in Table 17.

TABLE 17. Potential contribution of EU-funded R&I projects for flood adaptation policies

PROJECT NAME	FLOODS DIRECTIVE	EU ACTION PLAN ON THE SENDAI FRAMEWORK FOR DISASTER RISK REDUCTION	EU STRATEGY ON ADAPTATION TO CLIMATE CHANGE
AQUAVAL	Low	Low	Low
BASE	Medium	Low	Medium
BRIGAID	Medium	Medium	High
CASCADE	Medium	High	Medium
ECONADAPT	Low	Low	Medium
FAST	Medium	Low	Low
GRIn	Low	Low	High
LAND4FLOOD	High	Low	Medium
NAIAD	High	Low	Medium
OPERAs	Medium	Low	Medium
OPERANDUM	High	Medium	High
PEARL	High	Medium	Medium
PHUSICOS	High	Medium	High
PLACARD	Low	Medium	Medium
RECONECT	High	Medium	High
RESIN	Medium	Low	High
RESCUE	Medium	Low	Medium
RESCCUE	Medium	Low	Low
RISC-KIT	High	Medium	Medium
RISES-AM	Medium	Low	High
SECOaquaA	Low	Low	Low
SimetoRES	Medium	Low	Low
SMR	Low	Low	Low
UNALAB	Low	Low	High

6.4. THE EVIDENCE BASE: NBS FOR FLOOD RISK REDUCTION & COASTAL RESILIENCE

The review of NBS-related literature to date shows more reports of evidence for small-scale NBS (see Ruangpan et al., 2020). Also, within a range of small-scale NBS, certain measures have received greater attention compared to other measures, see for example Nagase & Koyama (2020). In terms of the risk-based economic assessment, which is a fundamental method for climate adaptation assessment, the majority of such economic analyses remain in the form of traditional cost-benefit analysis (CBA), see for example Gafni (2006).

The LIFE project AQUAVAL researched SUDS measures (infiltration basin, green roof, swales, etc.) in six sites across the Valencian region in Spain. The measures were implemented and analysed in relation to pluvial flood mitigation and the discharge of combined sewage into receiving watercourses. Monitoring results showed that the measures were effective in both flood mitigation and improvement of the water quality (Perales-Momparler et al., 2016).

There are numerous studies that address effectiveness of green roofs for rainfall-runoff reduction (see Table 18). For example, Burszta-Adamiak & Mrowiec (2013) performed experimental work at four roof platforms with different sizes and slopes in an urban area in Poland. The estimated effectiveness of green roofs for peak flood reduction ranged from 23% to 99% depending on the intensity and magnitude of rainfall events. However, they further conclude that more research at technical scale is needed to determine the role of the green roof slope, vegetation cover and drying process for runoff delay and peak reduction.

TABLE 18. Examples of effectiveness of small-scale NBS (see also Ruangpan et al., 2020)

NBS	SOURCE	EFFECTIVENESS	
		Runoff volume reduction	Peak flow reduction
Porous Pavements	Shafique et al., (2018), Damodaram et al., 2010	~30–65%	~10% - 30%
Green Roofs	Burszta-Adamiak and Mrowiec (2013), Ercolani et al. (2018), Carpenter and Kaluvakolanu, (2011), Stovin et al. (2012)	up to 70%	up to 96%
Rain Gardens	Ishimatsu et al. (2017), Goncalves et al. (2018)	up to 100%	~48.5%

TABLE 18. *cont.*

NBS	SOURCE	EFFECTIVENESS	
		Runoff volume reduction	Peak flow reduction
Vegetated Swales	Luan et al. (2017), Huang et al. (2014)	up to 9.60%	~23.56%
Rainwater Harvesting	Khastagir & Jayasuriya (2010), Damodaram et al. (2010)	~57.8-78.7%	~8%-10%
Detention Ponds	Liew et al. (2012), Damodaram et al. (2010), Goncalves et al. (2018)	up to 55.7%	up to 46%
Bioretention	Luan et al. (2017), Huang et al. (2014), Khan et al., (2013)	up to 90%	up to 41.65%
Infiltration Trenches	Huang et al. (2014), Goncalves et al. (2018)	up to 55.9%	up to 53.5%

Ercolani et al. (2018) also addressed the effectiveness of green roofs and performed a study in the Metropolitan city of Milan. They showed that such measures can be considered a valuable strategy to deal with frequent storms of smaller magnitude at urban watersheds. They further conclude that the planning of such measures should be done considering the local limitations of the drainage network conveyance capacity which can influence the effectiveness of green roofs. Li & Babcock (2014) reviewed the technical literature on green roof hydrology. They found that green roofs can reduce stormwater runoff volume by 30-86%, peak flow rate by 22% to 93%, and delay peak flows by 0-30 minutes, thereby decreasing pollution, flooding and erosion during precipitation events. They conclude that their efficiency can vary substantially due to design characteristics making performance predictions difficult.

Regarding coastal resilience, coastal habitats can reduce wave heights between 35% and 71% (Narayan et al., 2016). Restoration projects in mangroves and salt marshes for wave reduction can be several times cheaper than alternative such as breakwaters, for the same level of protection. They are also able to self-repair after strong storms and have much lower maintenance costs than artificial infrastructures (Narayan et al., 2016; see also Table 19).

TABLE 19. Examples of effectiveness of NBS interventions for coastal applications

NBS	SOURCE	EFFECTIVENESS	
		Runoff volume reduction	Peak flow reduction
Coral Reefs	Ferrario et al. (2014); Narayan et al. (2016); Debele et al. (2019)	~70-91%	~34 – 3200%
Salt Marshes	Ferrario et al. (2014; Narayan et al. (2016); Debele et al. (2019)	~72-92%	~5 – 425%
Mangroves	Ferrario et al. (2014; Narayan et al. (2016); Debele et al. (2019)	~31-53%	~32 – 260%
Seagrass	Ferrario et al. (2014; Narayan et al. (2016); Debele et al. (2019)	~36-58%	~258-949%

The EU continues to help build the evidence-base of NBS through various platforms and initiatives (Faivre et al., 2017). There are several NBS-related platforms, portals, databases, networks and initiatives at global, European, national and sub-national levels (Annex 1). Figure 27 illustrates the geographical spread of NBS-related projects, case studies and initiatives on climate adaptation and DRR taken from four EU platforms OPPLA, NWRM, Climate-ADAPT and Urban Nature Atlas.

OPPLA is an open platform on NBS, consisting of a knowledge market place, and it currently provides the most in-depth information out of all platforms reviewed. It contains 282 case studies with NBS that deal with DRR, climate change adaptation, biodiversity, food, sustainable cities, health and ecosystem services.

NWRM is a website that gathers information of European GI measures applied in the water sector. So far, there are 139 case studies in the database which spread across four sectors (urban, forestry, agriculture and hydro-morphology) with numerous cases that deal with DRR and climate adaptation (see also Table 20).

Climate-ADAPT is a platform supported by the EC and the EEA to help users to access and share data and information about NBS-related case studies and initiatives. The database includes adaptation options, case studies, guidance, indicators, information portals, organisations, publications and reports, research and knowledge projects, tools and videos. It supports a range of sectors such as agriculture, biodiversity, buildings, coastal, DRR, EbA, energy, finance, forestry, health, marine and fisheries, transport, urban and water management. Currently, there are about 100 case studies in the database.

The Urban Nature Atlas has been developed as part of the H2020 NATURVATION project and it contains 1000 examples of NBS from across 100 European cities. Projects included address various urban societal challenges and use nature as an inspiration to address these challenges.

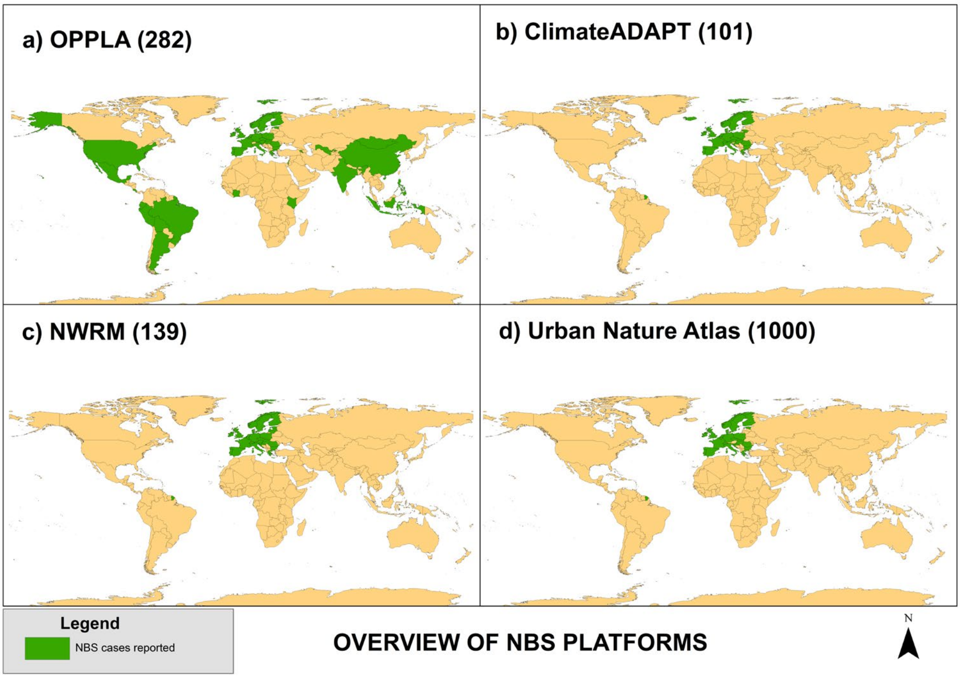


Figure 27. Illustration of the number of projects, case studies or initiatives and their geographical spread reported at different platforms (accessed May 2019).

TABLE 20. Examples of cases reported at the NWRM platform

NBS	PLATFORM, CASE LOCATION	FEATURES REPORTED
Green roofs, Permeable surfaces, Swales, Rain gardens, and Infiltration basins	http://nwrm.eu/case-study/climate-proofing-social-housing-landscapes London, UK	• 472 residents engaged • 90% of residents reported an increased understanding of climate change • 81% of residents said they agree or strongly agree that the quality of the green spaces has improved significantly • 58% of residents reported their use of the green spaces had increased • 48% of residents reported an increased sense of belonging • 67% of residents reported increased pride in the area they live in • 22 Green Team trainees involved (a training and employment programme for those who are young, unemployed and lacking experience and qualifications) • 11 job outcomes for Green Team trainees
Permeable surfaces, Swales, Filter Strips, Detention Basins and Retention Ponds	http://nwrm.eu/case-study/sustainable-stormwater-management-and-green-infrastructure-fornebu-norway Oslo, Norway	• Increase in water storage 230 m^3/ha • 60% reduction pollution Phosphorus (P) • 40% reduction pollution Nitrogen (N) • 80% reduction Total Suspended Solid (TSS) • 65% reduction pollution Copper (Cu) • 45% reduction pollution Zinc (Zn)
Permeable surfaces, Swales, Filter Strips, Soakaways Detention Basins, Retention Ponds, and Infiltration basins	http://nwrm.eu/case-study/leidsche-rijn-sustainable-urban-development-netherlands Utrecht, Netherlands	• Retained water 2,200,000 m^3/year • Increase water storage 1,000 m^3/ha • 80% reduction pollution Phosphorus (P) • 50% reduction Total Suspended Solid (TSS) • Potential for recreational activities in the water courses that will be created

6.5. INNOVATIVE GOVERNANCE (FLOODS & COASTAL RESILIENCE)

Governance plays an important aspect for achieving desired results from NBS interventions and some of the H2020 NBS projects are specifically dealing with innovative ways to promote sustainable governance of small- and large-scale NBS.

The NATURE4CITIES H2020 project defines governance in the context of NBS as "collective action arrangements designed to achieve the implementation of NBS". It identifies five main clusters of governance models which can be sourced from their study of 56 NBS cases across Europe. These five clusters are:

1. Traditional Public Administration: hierarchical governance structures and centralised government control of NBS.
2. New Public Management: 'public-private partnerships' and the corresponding 'hollowing-out' of government services.
3. Private-private partnerships: this would include sole governance of the NBS by private sector or community organisations, joint community-private sector co-governance, Sustainable Local Enterprise Networks (SLEN), etc.
4. Societal resilience: this is characterised by a high level of community leadership and low-level role played by governments.
5. Network Governance: recognises the necessity to engage many different actors in service delivery and the complexity involved in managing such networks effectively.

Clusters 3, 4 and 5 represent examples of new types of governance models. Cluster 5 has a similar concept to Polycentric governance proposed by the PHUSICOS project, which identifies three areas for governance innovation:

1. Polycentric governance which aims to involve multiple institutions and/or sectors (i.e., not only flood and coastal resilience but also natural conservation, planning, water quality, socio-economic organisations and others). This also could refer to engaging different stakeholders in open innovation processes that could identify problems or deliver solutions (e.g., citizens, academia, public authorities, businesses including SMEs, creative sectors and social entrepreneurs) (Martin et al., 2019).
2. Participation in the design, production and delivery phases by involving stakeholder participatory processes that co-determined the eventual shape of the NBS implemented. This helps to integrate user knowledge and provides insights into the tools they intend to use, to re-define operational processes and to create new working relationships beyond established departments and silos.
3. Financial incentives: local authorities designed and implemented novel incentives for households in consultation with villagers to monitor illegal logging in a nature reserve.

The work to date highlights the importance of analysing existing governance systems and actors prior to implementation of NBS projects. This is particularly important for large-scale interventions which may require careful consideration of legal frameworks of international cooperation on transboundary water governance.

6.6. BUSINESS MODELS & FINANCING (FLOODS & COASTAL RESILIENCE)

Collecting evidence about cost-effectiveness of NBS interventions has been the focus of many researchers and practitioners. However, systematic presentation of their construction, deployment, and operation and maintenance costs is still needed. In many cases, only aggregated costs of construction works can be found (e.g. information concerning their operation, maintenance and deployment costs is almost non-existent). This is partly due to the fact that NBS interventions differ in terms of hazard scales and types (e.g. pluvial, fluvial or coastal floods), climatic conditions and local contexts. Thus, their implementation costs will also vary, as will the nature of the borrower, business models and financing mechanisms. Also, there is a vast range of possible design and construction alternatives which adds further to the uncertainty (Keating et al., 2015). NBS schemes may also require the purchase of land and/or relocation of existing properties for which costs are not always reported.

In terms of the costs associated with implementation of green roofs, there is a significant price variation depending on their type, size, local conditions and country. Although they are known to provide good value for money when compared with other infrastructures, in some cases their high initial investment costs appear to be a barrier to implementation. Some examples of costs concerning implementation of small-scale NBS are given in Table 21.

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TABLE 21. Examples of costs of small-scale NBS (Ruangpan et al., 2020)

NBS	COST	SOURCE
Porous Pavement	~$252/m^2	Shafique et al. (2018), Damodaram et al., 2010
Green Roofs	~$564/m^2	Carpenter & Kaluvakolanu, (2011)
Rain Gardens	~$501/m^2	Ishimatsu et al. (2017), Goncalves et al. (2018)
Vegetated Swales	~$371/m^2	Luan et al. (2017), Huang et al. (2014)
Rainwater Harvesting	~$865/m^3	Khastagir & Jayasuriya (2010), Damodaram et al. (2010)
Detention Ponds	~$60/m^2	Liew et al. (2012), Damodaram et al. (2010), Goncalves et al. (2018)
Bioretention	~$534/m^2	Luan et al. (2017), Huang et al. (2014), Khan et al. (2013)
Infiltration Trench	~$74/m^2	Huang et al. (2014), Goncalves et al. (2018)

As part of the FP7 PEARL and H2020 RECONECT projects, Alves et al. (2019) address economic comparison of green-blue, grey and hybrid strategies for flood mitigation, and examine how this changes in view of the co-benefits. The NBS considered are small-scale NBS such as permeable paving, detention basins and rainwater harvesting. The authors also acknowledge difficulties in monetising the value of co-benefits (e.g., aesthetic value and biodiversity enhancement) and advocate for further advances in this direction. Some other studies provide quantitative data enabling to calculate annual values of those co-benefits which can be directly monetised (e.g. Woods-Ballard et al., 2007, Center for Neighbourhood Technology, 2010, Horton et al., 2016, Alves et al., 2019). Present value of co-benefits is often calculated for lifetime with discount rate, given per unit of measure.

Information on the costs concerning implementation of large-scale NBS is very scarce, and when it is reported, it also shows significant price variation. Nisbet et al. (2012) quote Saraev (2012) as follows: "While the potential of greenspace and woodland in particular to reduce stormwater run-off and reduce flood risk by slowing water flows is often acknowledged, economic estimates are scarce and tentative. The study, at Pickering, that provides economic estimates of the benefits of woodlands for flood management and erosion reduction reports a present value for these over 100 years of about £180 000 for 85 ha of woodland created". Table 22 gives examples of aggregated costs concerning implementation of large-scale NBS.

TABLE 22. Examples of aggregated costs of large-scale NBS interventions

NBS	COST	SOURCE
De-culverting (river restoration)	~€16.92 million	Chou (2016); see also Wild et al. (2019)
Floodplain lowering	~€136.7 million	Klijn et al. (2013)
Dike relocation/floodplain lowering	~€342.60 million	Klijn et al. (2013)
Floodwater storage	~€386.20 million	Klijn et al. (2013)

The H2020 CONNECTING NATURE project argues that business models and return-on-investments for NBS interventions are limiting interest from traditional financial institutions. The H2020 NATURVATION Urban Nature Atlas shows that almost 75% of NBS are funded from public sources (public budget / direct funding or subsidies). The same project, although not specifically focused on floods and coastal resilience, produced a Business Model Catalogue for Urban NBS with eight different business models (Sekulova & Anguelovski, 2017). These were identified based on a number of case studies of urban NBS, both in- and outside of Europe. This is also a dialogue tool for understanding what values can drive the realization of an urban NBS, and which stakeholders may be willing to pay for those values.

The H2020 RECONECT project, dealing with floods, is taking into consideration a variety of investment funds to support promotion and uptake of innovative investment strategies and business models for large-scale NBS, with similar cases covered by the H2020 OPERANDUM, PHUSICOS and NAIAD projects. The results from NAIAD which focus on floods demonstrate that viable business models (e.g., the natural insurance scheme developed under the NAIAD project) could play a significant role to increase the financing for the development of NBS. It has also been argued that NBS projects at different scales could support a diversification of risks and help the development of a larger portfolio of return on investments (e.g., Marchal et al., 2019).

6.8. POLICY RECOMMENDATIONS & R&I GAPS (FLOODS & COASTAL RESILIENCE)

6.7.1. Policy recommendations

As a more general comment, it is necessary to better connect the three policy instruments in relation to how they foresee NBS interventions and also, where appropriate, connect with the Water Framework Directive (WFD). The policy documents must be carefully coordinated in this respect or otherwise there is a chance that the process of implementing NBS may become less effective or even hampered. More specifically, the process of implementing NBS provides an opportunity to maximise synergies between the FD and the WFD by identifying multifunctional cost-effective measures which can result in win-win measures being implemented. This will enhance further coordination during the development of flood risk management plans as well as river basin management plans (FRMPs and RBMPs) at national levels.

Furthermore, the need for implementation of NBS provides an opportunity to achieve better synergy and coordination of efforts at the EU and national Member States levels through integration of such measures into the national and local policy instruments of Member States. In some cases, such local policies already exist and the appropriate actions are being implemented. For example, following research efforts, the City of Hamburg's policy on green roofs was implemented in 2015 such that no less than 70% of all suitable rooftops are to be topped with vegetation. In Belgium the Brussels Region's Regional Planning Regulations (Title I, Chapter 4, page 19, Article 13) require transformation into green roofs of flat roofs with an area of >100 m^2. This is applicable for any totally or partially inaccessible roof, for main buildings and annexes. To this end, identifying areas of synergy between policies at different levels, where common goals can be met at the same time, can strengthen the capacity to achieve the EU-wide response. This would ensure that the uptake of NBS is carried out in a systematic and coordinated manner.

The European Green Deal (EGD) sets an agenda for transforming EU's economy and society into a more sustainable path. In doing so, the EGD has a strong focus in protecting the health and well-being of citizens from natural or man-made disasters including floods. Furthermore, in view of the current pandemic situation and discussions at the EU level to ensure post COVID economic recovery, the related funds need to be consistent with the EGD which in turn provides an opportunity to integrate NBS in these discussions. Given that one of the cornerstones of the EGD is to enhance the EU's natural capital and that natural capital can significantly contribute to reducing the impact of floods, NBS can play a significant role in stimulating economic growth that will put EU in the path of "building back better".

Some key recommendations concerning the Floods directive are summarised below:

- There is a need to better address data and model uncertainties which in turn can have significant impacts on estimation of peak discharges and corresponding flooded areas (see for example Eleftheriadou et al., 2015). This is particularly important when NBS interventions are considered.

- The work concerning analysis and planning of NBS should be done for a range of scenarios combining different land use characteristics, urbanisation, climate trends and other future projections. Furthermore, vulnerability and risk analysis should be considered as dynamic processes which continuously evolve through time (see also Tsakiris et al., 2009).

- All possible types of floods should be equally addressed. The analysis of hazards should also combine multiple sources and events as well as their cascading effects. Delineation of flood hazard maps should combine different variables (e.g., flood depths, velocities, durations and concentrations of pollutants) depending on the processes that dominate different flood types.

- The search for measures should encourage consideration of different kinds of measures (grey, small- and large-scale NBS) and their hybrid combinations.

Key recommendations on the EU Climate Change Adaptation Strategy are that:

- Inclusion of co-benefits from different measures (which is particularly relevant for NBS) will ensure that climate adaptation is undertaken in a timely, cost-effective and sustainable manner. This also refers to indirect effects of floods (i.e., human well-being, culture value, etc.) and these should be taken into account in assessing costs and benefits of adaptation and risk management;

- Stakeholder and citizen participation in adaptation decision making should be promoted at all levels of governance;

- Economy-wide assessments should be used to analyse the efficiency of adaptation decisions at a national and wider European level;

- Agriculture sector authorities at the EU level and Member States are one of the key stakeholders for the planning of large-scale multipurpose NBS interventions. The policy should also include the agriculture sector and promote NBS as cost-effective multipurpose adaptation options.

Key recommendations concerning the EU action plan for the SFDRR include:

- Key Area 2 ('An all-of-society approach in disaster risk management') would benefit from some concrete examples of how to strengthen the links between disaster risk management, climate change adaptation, forestry and biodiversity strategies. This could be given through numerous examples of NBS for different scales of intervention. For example, there is growing awareness that NBS can provide simultaneous benefits such as protection from floods, mitigation of climate change, biodiversity enhancement and other ecosystem services. The three H2020 large-scale NBS hydro-meteorological projects (OPERANDUM, PHUSICOS, RECONECT) will soon have evidence available to support this.

- Regarding Key Area 3 ('Promoting EU risk informed investments'), this area could be strengthened by providing some concrete examples of mechanisms for flood-related disaster risk financing, risk transfer and insurance, realised in NAIAD.

- Discussion concerning Key Area 4 ('Supporting the development of a holistic disaster risk management approach') should make a more explicit reference to the benefits of NBS for DRR. Large-scale NBS are particularly relevant for flood-related disasters in view of their capacity to deal with extreme events. Also, a 'building back better' approach, which is defined within the same priority area, refers not only to rebuilding of disaster-resilient infrastructure, but also to building of disaster-resilient ecosystems and societies. Hence, the existing document should make a more direct connection between the benefits/co-benefits of NBS interventions and pre- and post-DRR responses.Research and innovation gaps

There is a large body of knowledge and evidence produced through various EU research programmes and actions and through the Commission's own internal scientific services (Joint Research Centre). A joint publication between the three EU-funded large-scale NBS projects RECONECT, OPERANDUM and PHUSICOS identified a number of remaining research and innovation gaps which could provide a good basis for future research programmes (e.g., Horizon Europe) to address NBS interventions for hydro-meteorological risk reduction (Ruangpan et al., 2020). Some of the key research and innovation gaps are summarised below:

Barriers - Despite the numerous reports on the effectiveness of NBS (e.g., Kong et al., 2017; Zölch et al., 2017; Versini et al., 2018), in practice, these measures are still being applied at a slow rate while grey infrastructure remains as a preferred choice (e.g., Dhakal & Chevalier, 2017; Qiao et al., 2018).

This situation can be attributed to several barriers which range from political (e.g. NBS require longer periods of time to generate benefits while politicians tend to prioritise investments to those interventions that generate outcomes in shorter or immediate future); governance (e.g. many water and environmental management authorities operate in silos and often follow different visions, goals and regulatory frameworks while successful implementation of NBS requires full cross-sectoral cooperation); social (e.g. NBS represent a relatively new approach and there can be a negative perception due to uncertain outcomes and preference towards traditional hard engineering "grey infrastructure"); and technological. From the technological point of view, limited implementation of NBS for flood risk reduction is mainly due to the lack of sufficient technical references, design standards and guidelines (Qiao et al., 2018). Furthermore, there is still a general perception that the construction and especially maintenance of NBS are more costly than traditional grey infrastructure measures (see for example, Dhakal & Chevalier, 2017). Therefore, a more substantial knowledge and evidence base is needed in order to promote their wider acceptance and upscaling/uptake (see also Kabisch et al., 2017).

General knowledge and evidence base of small-scale NBS – With respect to small-scale NBS, apart from the need to continuously gain further evidence on their individual performance characteristics in different settings (i.e., different climate conditions, quantity and quality, cultural and governance contexts, single and multiple hazards, etc.) and associated costs, more efforts are needed to address the full potential of their co-benefits and how these can be quantified and/or monetised. Furthermore, the question concerning performance of "networks" (or "trains") of interconnected small-scale NBS, as well as their hybrid combinations with large-scale NBS and grey infrastructure still remains unclear and should be addressed in the future work (see for example the work of Wild et al, 2002; Damodaram et al., 2010; Dong et al., 2017; Huang et al., 2014; Luan et al., 2017).

General knowledge and evidence base of large-scale NBS – There is a large gap between the amount of research concerning small scale NBS in urban areas and large scale NBS at the catchment (or river basin), rural, coastal and regional level. Hence, further research concerning their performance individually and in hybrid combinations with small-scale NBS and grey infrastructure would be very beneficial. This is also a focus for research in RECONECT, which in turn may indicate directions for future work. Understanding of the associated natural processes and how they change over time would also prove invaluable information. Platforms and databases with lessons learnt and their implementation costs (e.g., construction, monitoring, operation and maintenance and decommissioning costs) should be developed and kept up to date. There is an opportunity to expand OPPLA (and other NBS-related platforms) to incorporate the evidence base for large-scale NBS.

Planning tools – Currently, the tools, such as real-time data acquisition and modelling, optimisation algorithms and decision-support systems, which are necessary for planning and implementation of NBS, are rather scattered and incomplete. Also, to support efforts for wider uptake of NBS it is necessary to advance the methodologies and tools for systematic evaluation of benefits and co-benefits (especially those related to social and ecological system, e.g. aesthetics values, community liveability, and human health), frameworks and methods for optimal selection of “hybrid measures” (i.e. combinations of grey infrastructure and small- and large-scale NBS). This aspect is being addressed in the three large-scale NBS projects (i.e. RECONECT, OPERANDUM and PHUSICOS) and the results that will be obtained could provide a basis for future research activities.

Operational tools – Further efforts should also be placed on the developments of tools that combine real-time monitoring and control systems, advanced flood risk assessment methodologies and models, smart early warning systems, numerical weather prediction models and flood risk models to advance real-time operational potential of NBS (i.e. development of SMART NBS), key focal points in RECONECT.

Standards, guidance and design tools – Development of practical design standards, guidance documents and supporting tools would also be very beneficial. This would maximise the chances for their multi-functionality and minimise the chances for their undesirable performance effects.

Stakeholder participation - There are also several challenges associated with stakeholder participation. The future work should maximise the use of decision-support platforms and online tools for this purpose. All three large-scale NBS projects are addressing the co-creation and decision support processes in detail.

Nature-based Solutions for microclimate regulation and air quality

Carlo Calfapietra

7. NBS FOR MICROCLIMATE REGULATION AND AIR QUALITY

7.1. INTRODUCTION

7.1.1. Local climate regulation in a climate change context

It is known that cities are generally warmer than the surrounding areas and this will be particularly challenging in the current scenario of climate change (Saaroni et al., 2018). While Southern European countries are historically used to cope with high temperatures especially in the urban environment, recently also Central and Northern European cities are starting to experience this issue and take countermeasures. Rosenzweig et al. (2015) shows an increase of mean annual temperatures in 39 cities worldwide by a rate between 0.12 and 0.45 °C per decade over the 1961-2010 time period (see also section 3 on climate change mitigation).

The increase of temperatures in city centres can reach different degrees in some cases as compared to rural areas, due mainly to the hard surfaces, heating systems, traffic, and decreased turbulence in cities. While the primary concern is the issue of thermal comfort, in some cases, especially in Southern climates, this can lead to extreme temperatures which might induce heat shocks, dangerous especially for children and elderly people.

Figure 28. Urban trees are among the most effective NBS for improving thermal comfort of cities and to generally improve health and well-being; in a number of EU projects this has been studied, as mentioned below, with examples of cities from different latitudes as case studies (photo: G. Sgrigna).

Besides the direct effects on people, increased temperatures in the urban environment can have important implications on urban vegetation including changes in the growing season and making it more susceptible to frost damages, heat shocks, or pest attacks. In some cases, however, this can also result in increased growth and productivity.

Warming, in conjunction with other factors such as increased pollution, decreased precipitation (due to the impermeable surfaces) or increased CO_2 concentration (often observed in urban environments), have crucial impacts on the adaptation capacity of urban plants, which in turn can affect the mitigation potential of green infrastructure (GI) and more generally their ecosystem services provision (Calfapietra et al., 2015).

The effects of NBS on microclimates can occur through shading, through evaporative cooling, or through wind shielding, for instance in the case of shelter belts (Akbari et al., 2002). While in the first two cases different forms of NBS (urban forests, green roofs and facades, urban GI and any plant-based solutions) can be used, for the latter the tree component is of particular relevance (Figure 28 above).

Using NBS to reduce urban heat island (UHI) effects has not only implications for the thermal comfort of people and of the urban ecosystems but can contribute considerably to energy savings and to indirect CO_2 savings, thus considerably contributing to the EU Green Deal's overall aim of carbon neutrality by 2050. Some studies show for instance that this can be very relevant especially in hot climates where investment in air conditioning is very high.

As an example, the indirect carbon saving related to the shading and cooling effect can be 3 times or bigger than the direct carbon sequestration by the same tree (Rosenfeld et al., 1998; see also section 3 on climate change mitigation). This is also in line with the Strategy on Heating and Cooling (COM/2016/051) where it is clearly stated that "Nature-based solutions, such as well-designed street vegetation, green roofs and walls providing insulation and shade to buildings also reduce energy demand by limiting the need for heating and cooling" (EC, 2020).

7.1.2. Air pollution in European cities

With the increasing urban population in most of the European countries and worldwide, air quality in cities becomes a priority. The number of exceedances of air quality limit values in urban areas for a number of pollutants is increasing due to a number of reasons such as unfavourable meteorological conditions, or difficulties in controlling sources or precursors of certain pollutants.

In particular, the EU Directive 2008/50/EC on air quality regulation aims to secure cleaner air for Europe, establishing air quality standards to be implemented by the member states (EC, 2019f), and focusing particularly on particulate matter (PM), nitrogen oxides (NOx), O3 and benzene (see also Figure 29 below).

Recent information from the World Health Organization (WHO) shows that for EU member states the situation is particularly critical. For instance for PM2.5 74-81 % of the population were exposed to concentrations above the WHO guideline values set for the protection of human health while for O3 this percentage of population reached 95-98% (EEA, 2019).

Although the first concern of air quality in the urban environment relates to human health we should not neglect the impact on urban ecosystems and biodiversity including either vegetation and animals. The effects on urban ecosystems can sometimes influence biodiversity, such as the growth and the phenology of plants or even visual symptoms that can be used as a tool for biomonitoring, e.g. with lichens or sensitive plants (Branquinho et al., 2015).

NBS are considered highly effective in taking up or removing a number of air pollutants. As mentioned above, plants' tolerance to air pollution should be considered because damage to the physiological status can also decrease drastically the mitigation potential and the ecosystem services provision (Calfapietra et al., 2015). In achieving this, NBS can provide a crucial contribution to some objectives of the EU Green Deal. For instance, the Commission will adopt in 2021 a zero pollution action plan for air, water and soil. It is known that NBS can be very useful in reducing pollution in different environments (Grote et al., 2016) and in a number of ongoing international and local projects are testing which NBS can be more efficient, depending on the pollutant and climate conditions.

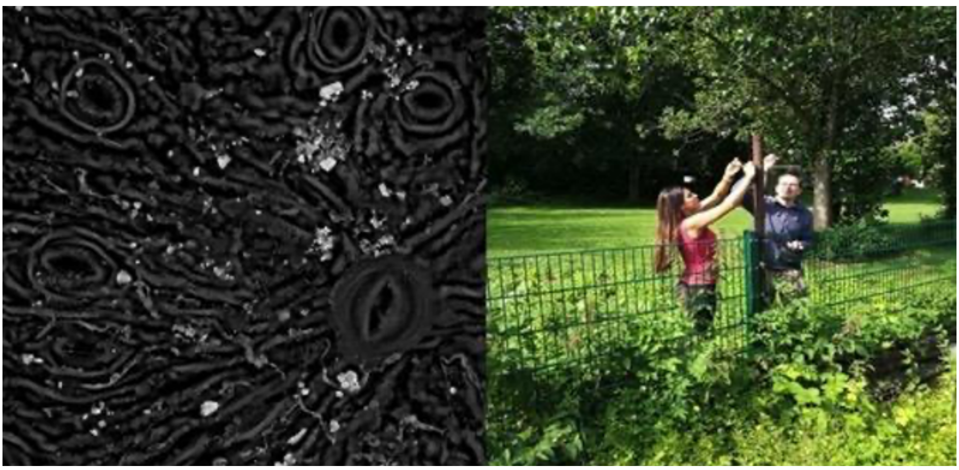

Figure 29. NBS characterised by the use of vegetation are highly effective for air pollution mitigation either in the case of particles deposited on the leaves and of gaseous compounds mainly absorbed through stomata. Left: Examples of Scanning Electron Microscope (SEM) images to detect morphology of leaves, number and quality of particles and stomata properties. Right: passive samplers installed in Dortmund to determine the role of NBS in air pollution mitigation. Source: PROGIREG project. Photo: G. Sgrigna and G. Guidolotti).

Most importantly, scientists are defining the amount of pollutant removed for each type of NBS - developing indicators that will allow the measurement per unit of time and space of what could be their "remediation potential", in the case of polluted environments, or the "avoided pollution" in the case of future planning and management strategies (Nowak et al., 2014; Grote et al., 2016; Tiwary et al., 2019).

Amelioration of air pollution can occur in different ways, for instance through stomata absorption in the case of gaseous pollutants, or through deposition as in the case of particles. The great diversity of air pollutants, and the diversity in response by individuals either in terms of sensitivity and air pollution mitigation potential, further complicates the selection and design of optimal NBS for particular city contexts (Samson et al., 2017).

Moreover plant-based solutions can in some cases provide ecosystem disservices in terms of air quality and their choice should thus be carried out with great care (see also Figure 30). In particular we refer to pollen emissions and biogenic volatile organic compounds (BVOCs), which many plant species emit. Nowadays, the pollen load and allergenicity potential of most species are known (Carinanos et al., 2015) as is BVOC emission and the relative potential ozone formation (Calfapietra et al., 2013). Thus the choice of plant species in different environments can take into account these properties as mentioned in the evidence-base section that follows.

O_3	50-60%
UFP	0-90%
PM_{10}	15-50%
NO_x	20-50%
SO_2	≈10%

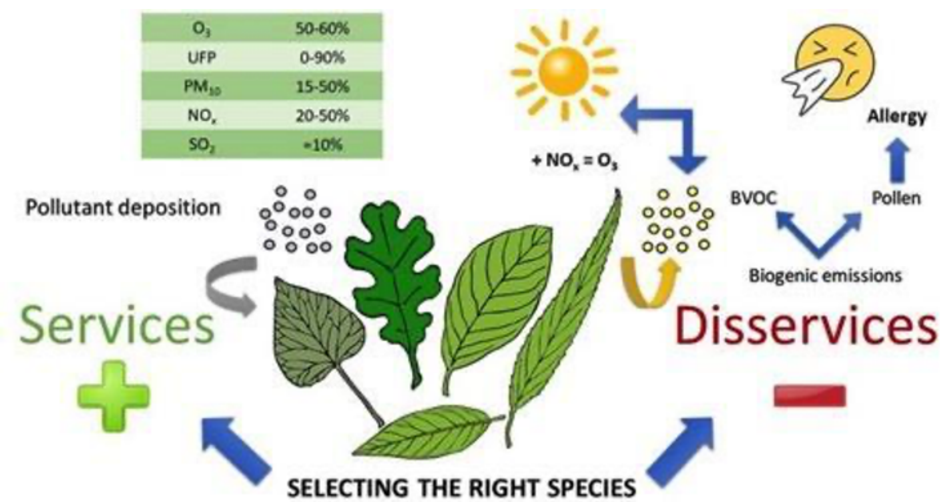

Figure 30. Air quality services and disservices provided by NBS. The choice of the right species can maximize services and minimize disservices; data in the table refer to green wall and green roof air pollution percentage reduction as extrapolated from Abhijit et al., 2017 (O3: ozone, UFP: Ultra-fine particles, PM: particulate matter, NOx: nitrogen oxides, SO2: sulphur dioxide, BVOC: biogenic volatile organic compound
Source: after ISCAPE project and Kumar et al. (2019).

7.1.3. Physical and mental health implications.

NBS are a fundamental component of life quality, increasing health and well-being, restoring cognitive resources during hot summers, improving townscapes and favouring social cohesion (Hartig et al., 2011). Integrated interdisciplinary approaches, including the study of human behaviour, can strengthen our understanding of this wide research area (Carrus et al., 2015).

A recent review of reviews found that public health and natural environments are positively related for a number of services including socio-behavioural/cultural ecosystem services as in the case of stress and physical activity, regulating ecosystem services as in the case of heat reduction and specific health benefits as in the case of cardiovascular mortality or respiratory diseases (van den Bosch & Sang, 2017).

Focusing on thermal comfort, southern cities are not alone in experiencing problems with increasing temperatures related to UHI and climate change - Northern countries including Russia and the Netherlands are experiencing increased mortality rates (Norton et al., 2015). Cities in southern climates can, however reach temperatures leading to heat shocks such as close to 50°C and thus the impact of UHI can have drastic effects on mortality rates; the deterioration of life quality related to non-extreme temperatures is also becoming an increasingly important problem for EU cities, regions and Member States.

Of particular concern is the expected effect of air pollution on human health caused by increased risks of cancer related to PM but also heart and respiratory diseases, respiratory infections and obstructive pulmonary diseases (Loomis et al., 2013). The effects of PM and O3 pollution are considered to be responsible for 406,000 premature deaths in Europe as analysed in 2012 (Amann et al., 2012).

NBS are proven to be effective in reducing UHI and improving air quality provided that the right species are chosen. In addition to having a direct effect on physical human health they offer significant advantages for improving mental health. Recreational activities based on NBS are strongly appreciated and provide useful results in the therapy of certain psychological conditions and wellbeing outcomes (Scartazza et al., 2020).

NBS related to blue spaces (fountains, rivers, lakes, coastal areas) in urban areas, not only help cities adapt to climate change by reducing heat stress, but also improve mental health and psycho-social wellbeing. Results are generally inconsistent and mixed across studies, with very few findings for direct physical health benefits (Gascon et al., 2017; Britton et al., 2020). Interestingly, green and blue spaces together have been shown to favour cognitive and social development in children affecting parameters related to behavioural development and symptoms of attention deficit/hyperactivity disorder (ADHD) (Amoly et al., 2014).

More generally, the concept of well-being can be extended to all situations where NBS offer improvements to the quality of life directly or indirectly. Understanding the role that different blue and green spaces and more generally the role that biological diversity can have on physical, mental and spiritual health and well-being, is being investigated more and more frequently in a number of studies (Raymond et al., 2017; Marselle et al., 2019).

7.2. EVIDENCE BASED ON PROJECTS, INCLUDING NBS ASSESSMENT & FINANCING

7.2.1. NBS for reducing the Urban Heat Island effect

It has been shown that Mediterranean cities will experience a drastic increase (up to 60%) of the number of heatwave days but the biggest increase (up to 14°C) in the severity of heatwaves will be in cities of central Europe (Guerreiro et al., 2018). The RAMSES project has carried out an analysis of the surface UHI for more than 100,000 villages in Europe and the Middle East and North Africa (MENA) region along with an assessment of structural features of cities and how they relate to heat islands for the 5,000 largest European cities.

Considerable efforts have been taken to establish and test operational UHI forecasting system pilots, taking mainly Mediterranean cities as case studies as in the case of the LIFE project ASTI. Several studies have analysed the effect of vegetation or more complex NBS in ameliorating thermal discomfort associated with UHI. In this context, NBS encompass green roofs, urban forests, parks or customized shading facilities which can significantly decrease local temperatures (see Table 23). The concept of Park Cool Island has been introduced to define the temperature gradient between green and urbanized areas. Park Cool Island can be influenced by vegetation type, morphology of the area, size of the green area and weather conditions (Hiemstra et al., 2017; Table 23).

TABLE 23: Examples of studies of NBS effect on thermal mitigation in different European case studies (after GREENINURBS project and Hiemstra et al., 2017)

COUNTRY	TEMPERATURE MITIGATION (°C)	NBS / VEGETATION TYPE	REFERENCE
Israel	2-4	Grass lawn / trees	Shashua-Bar et al., 2006
Portugal	2.5-6 and up to 9	Green areas	Andrade & Vieira, 2007
Netherlands	0.6 and up to 4	Green areas	Heusinkveld et al., 2014
Sweden	2-4 and up to 6	Parks	Upmains et al., 1998

Similarly, in the BRIDGE project, a strong effort has been put in modelling the impact of vegetation on UHI (Lindberg & Grimmond, 2011) and has been applied in a number of case studies such as in London, UK, with reductions of temperatures in the order of the 3°C and significant co-benefits including flood risk management outcomes. OPENNESS, in turn, produced an article about the limited capacity of urban green spaces in reducing heat island effects in the city of Barcelona which led to total city-based annual GHG emissions savings of just 0.47 % (Barò et al., 2014).

BOX 52. The BASE project analysed the impact of various NBS to reduce UHI in different EU cities and formulated a number of adaptation options for different future scenarios. The resulting guidelines recommend strategies that can be implemented in various city contexts.

NBS may affect wind turbulence and thus both the effect on UHI and the perception of it, as shown in the following studies. A key effect, especially when temperatures are high, is that reduced ventilation by GI can increase thermal discomfort (Gartland, 2012). Many studies mention the importance of GI in altering wind regime, yet surprisingly little quantitative data are published on the various case studies analysed. In other studies it has been observed that, during nights, airflow around urban parks of Northern European cities affects microclimate in the nights up to about 250 m from the green area (Eliasson & Upmanis, 2000).

Humidity is an important factor affecting the cooling effect of NBS. Several studies investigated this relationship, particularly in Mediterranean cities, and mainly in relation to the contribution by evapotranspiration (often considered in microclimate modelling). Evapotranspiration by urban trees can vary by up to 3 times depending on the species and the cooling effect, which is generally due to the incoming solar radiation being converted into latent heat flux (Konarska et al., 2016).

BOX 53. The RAMSES project found that in northern cities such as Antwerp, increasing green areas from the current 25% land coverage to 60% would allow an average cooling of around 0.6°C, although the effect is mainly limited to the surrounding areas of larger parks.

Besides trees, green roofs and green walls are also considered to be effective in ameliorating microclimate, especially at the building level - which can also reduce drastically the energy consumption, thus impacting considerably the carbon footprint at city level (Lehmann, 2014; see also climate change mitigation section in this report). A review of studies of the performance of reflective and green roofs, concludes that at the city scale, green roofs can have overall effects of reducing city temperatures by between 0.3 and 3°C (Santamouris, 2014).

Regarding the implications of microclimate regulation for climate change policies (namely the reduction of the carbon footprint of cities) and their economic impacts at various scales, there exists little or no evidence based on European case studies. As shown in Figure 31, any NBS which is producing a thermoregulation effect on a building's energy balance is consequently producing an indirect CO_2 saving. This is generally correlated to the savings in air conditioning in hot climates but can be associated also to reduced heating in cold climates (see also section 3).

Quantitative information derived from North American studies shows the impact of tree locations on heating- and cooling-energy use, resulting in savings between 2% and 7% (Akbari et al., 2002). Converting this in energetic and economic costs for a number of Australian cities, it has been estimated that electricity savings of cooling by 2°C would produce annual cost savings per household per year between 25 and 37$, depending on the considered scenario and the typology of air conditioning system (Whiteoak & Saigar, 2019). Case studies from Melbourne show that the effectiveness of cooling is associated with water sensitive urban design, which is related to the potential development of vegetation (Tapper et al., 2019).

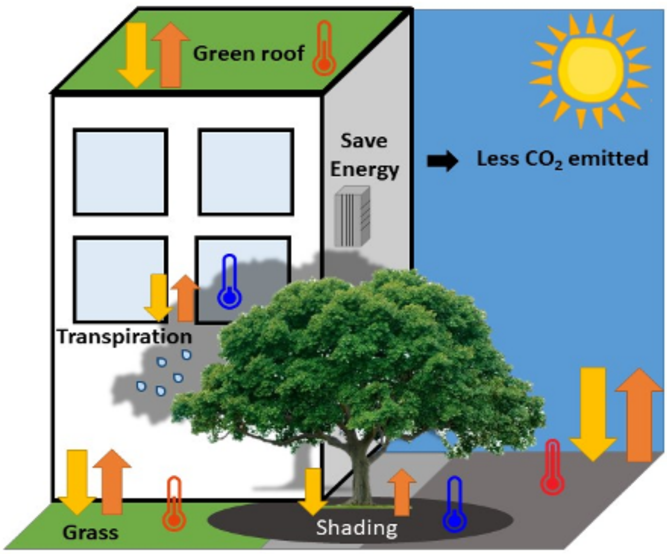

Figure 31. NBS influence the energy balance by shading and transpiration, reducing the incoming solar radiation and the thermal energy emitted from surfaces. Water transpired by plants contributes to the cooling of air temperature. A lower energy input on buildings leads to a decrease in the use of the air conditioning in turn reducing the energy consumption and CO_2 emissions and providing also an economic saving. Image: R. Pace

7.2.2. NBS for air pollution mitigation

Plants and notably trees are particularly efficient solutions in removing pollutants (Kroeger et al., 2014, Yang et al., 2008). Herbaceous species can be particularly useful components of green walls and green roofs, especially in very dense areas where the use of trees is not recommended for space or maintenance problems. Differences between tree and herbaceous components are related to the potential development of the crown of the trees, expanding the extension of the leaf area per unit of ground area, known as Leaf Area Index. Obviously, since it is not always possible to keep tree branches extended in the architectural greenery, alternating green walls and roofs with the use of herbaceous plants can be a valid option.

Optimum planting regimes to improve air quality may involve factors including crown architecture, leaf morphology, stomata abundance and opening, physiological and phenological characteristics. Clearly also the seasonality is a crucial issue because the presence of leaves besides to the thermal conditions are crucial parameters to regulate stomata opening which regulates the uptake of gaseous pollutants and also the cooling by evapotranspiration. However, in the case of PM, evergreen species can mitigate pollution also in winter despite the scarce physiological activity, as we mainly deal with a deposition on leaf surface. This appears particularly relevant for Northern cities as we often register high concentrations of PM just in winter due to the meteorological conditions and the emissions from heating (Grote et al., 2016).

A number of studies have evidenced the differences and the performances of various species in absorbing O3 (Calfapietra et al., 2016) or PM (Sgrigna et al., 2020). Besides traditional techniques in the lab or sampling in the field, new techniques allow for the determination of the role of entire ecosystems or urban parks in absorbing air pollutants. For instance, the eddy covariance technique enables measurement of the exchange of gases and particles between the canopies and the atmosphere at a very high frequency (Guidolotti et al., 2017).

Modelling approaches have also been developed to calculate the possible contribution of new planting programs in air pollution mitigation. The most widely used is the i-Tree model (formerly UFORE, Urban Forest Effects) developed by USDA and later implemented worldwide (Hirabayashi et al., 2012). The model enables urban GI design with a particular focus on urban forest and its contribution to absorb a number of air pollutants including O3, PM2.5, NOx and SO2. Specific modules are also available for CO_2, BVOC emission, energy savings and urban runoff performance. For the USA, the estimated value of removal of air pollutants (using i-Tree) is close to 17 Millions tons per year with a total economic value of about US 7 Billion (Nowak et al., 2014). The model has now been applied in a number of city case studies in Europe such as Barcelona (Barò et al., 2014) and also in the framework of a number of European projects such as OPENNESS and PROGIREG.

The BRIDGE project has used various different modelling approaches to assess the contribution of trees in London in removing air pollutants. It estimated between 852 and 2121 tonnes of PM10 removed annually i.e. between 0.7% and 1.4% of PM10 from the urban boundary layer. Interestingly, the impacts of potential increases in tree cover were also modelled and it is estimated that increasing canopy cover by between 20 and 30% (which is an amount that a number of cities are considering in realistic future plans), could improve PM10 removal in a range of 1.1–2.6% by the year 2050 (Tallis et al., 2011).

Among the large funded European projects, few have directly investigated the interaction between air quality and the air pollution mitigation potential of NBS. ISCAPE investigated how various types of urban greenery can affect air quality in open space such as open roads or street canyons conditions. It has been concluded that while in most cases GI may deliver air quality improvements in some cases the presence of trees (for instance within narrow street canyons) may worsen environmental quality by diminishing dispersion and increasing concentrations of pollutant particles at pedestrian level (Abhijit et al., 2017; Figure 31).

In this respect the issue of scale is crucial: as observed by Tiwary et al. (2019), the effect of NBS at microscale (i.e. ranging between 10 and 500 m) is mainly driven by exposures through deposition and pollutant redistribution while at the macroscale (i.e. in the range of kms) the key processes are the atmospheric turbulence and deposition, making the estimation of air pollution mitigation potential by NBS and related models even more complex. Other aspects which have been investigated in the interaction between NBS and air quality are those considered "ecosystem disservices": the emission of BVOC and the allergenicity related to pollen release.

BVOC emissions are particularly important in urban environments and particularly in hot climates due to the photochemical reactivity and possibility to exacerbate the formation of O3 and other secondary pollutants. This happens especially in situations characterised by high concentrations of NOx and low concentrations of VOC, thus NBS should consider this factor in particular in the conditions mentioned above (Calfapietra et al., 2013). Considerable evidence now exists regarding emission factors of the main plant species and databases are available worldwide, which could allow a more careful choice of the plant species especially in cities where the photochemical risk is higher[16]. It is thus possible to properly consider BVOC as a factor in new planting programmes (Simpson & McPherson, 2011).

Within the framework of the GREENINURBS project, the ‘Specifind’ tool has been developed to support plant species selection in European cities taking into account climatic conditions and with a particular focus on air quality, carbon sequestration, allergenicity and energy saving (see Figure 32 for details).

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[16] ‘e.g. http://www.es.lancs.ac.uk/cnhgroup/download.html

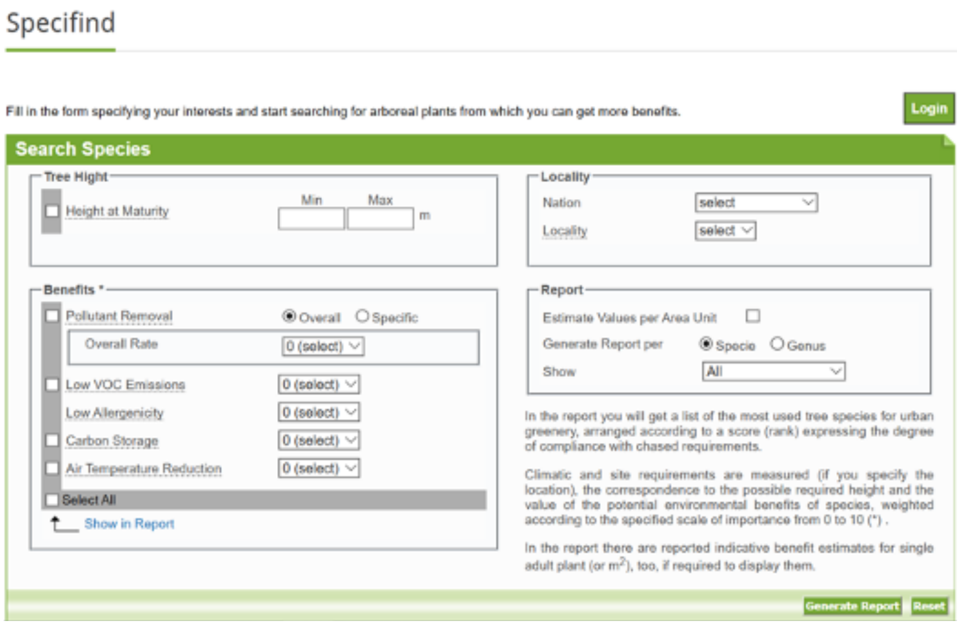


Figure 32. In the framework of the GREENINURBS project the tool 'Specifind' has been launched. The tool allows to select, for the largest cities in Europe, the best tree species, based on a number of parameters. These include air quality amelioration, carbon storage, allergenicity and air temperature reduction. Other than ranking the best species, the output also provides the total amount of benefits produced.

7.2.3. Evidence of the benefits of NBS for human health and well-being

The role of NBS in improving health and well-being is being demonstrated in a number of projects, however estimating and quantifying those benefits is far from simple due to the number of variables and the difficulty in proving causality between various factors affecting health improvements. Thus it is often suggested, as in NATURVATION, to combine several methodologies based on different indicators and to include questionnaire surveys of perceptions on health and well-being, along with the accessibility, proximity and quality of green areas (Davis et al., 2018).

Not only green spaces, but also blue spaces have the potential to improve health and well-being considerably. In a recent review developing from the BLUEHEALTH project and including 35 studies, a positive relationship between exposure to outdoor blue spaces and both benefits to mental health and well-being and levels of physical activity have been demonstrated (see also Figure 33 below). Less consistent was the link between outdoor blue space exposure and general health, obesity and cardiovascular diseases (Gascon et al., 2017).

One of the factors frequently analysed in EU NBS projects is thermal comfort. The BASE project, for instance, elaborated a tool named Urbath to assess site-specific heat stress levels under different conditions and in relation to urban planning projects and coupled different adaptation options for the selected scenarios and cities (Meyer et al., 2015).

The index Physiological Equivalent Temperature (PET) is an advanced human thermal comfort index which has been used in a number of projects aimed at evaluating the role of NBS to ameliorate urban heat stress. A number of models have been used for this. Envi-MET is commonly applied in case studies such as the city cases investigated by RAMSES and CLARITY[17]. Acero & Herranz-Pascual (2015) have demonstrated ENVI-met can be used to provide fine-grained spatial resolution modelling of NBS benefits as it was undertaken for the city of Bilbao, to compare different greening scenarios to improve outdoor thermal comfort conditions. In particular, they demonstrated the importance of considering different vegetation systems, concluding that using trees and grass in the selected street canyons could allow a PET reduction of up to 10°C.

A Heat Health Watch Warning Systems (HHWWS) has been developed by the LIFE project ASTI which is using for various case study cities, including Rome and Thessaloniki, for which a heat shock warning system has been developed based on weather forecasts. The system also includes an estimation of the mortality rates related to heat wave days which derives from both predicted and observed data. This appears to be highly significant especially in Mediterranean areas where temperatures and UHI are touching extreme values.

An interesting issue unfortunately investigated in very few studies is the impact of NBS on wind speed reduction, which can have primarily implications for thermal comfort but also in terms of the exposure of pedestrians to air pollution (Amorim et al., 2013). This aspect is particularly relevant for areas where tree densities are high such as in boulevards, groves and urban forests. On the one hand, planted trees can alleviate thermal comfort through shading, on the other hand they can affect ventilation, thus being negative for thermal comfort. While this is true for UHI in warmer cities, it can also exert positive effects in cold climates by moderating wind chill effects (Gartland, 2012). In the GREENINURBS project an analysis of different case studies led to the conclusion that the reduction of thermal stress through the use of vegetation depends on the following factors (Hiemstra et al., 2017):

- the increase of green areas and particularly of urban forested areas;
- the choice of plant species can drastically increase UHI mitigation efficiency;
- the combination of small green spaces within a dense network of streets and squares with larger green areas increases the capacity to mitigate UHI;
- the combination of green walls and roofs, street trees, or vegetated terrains is the best way to decrease the temperature, especially in street canyons;
- the larger the trees, the better the capacity to contribute to thermal comfort; and
- water availability at city level and the presence of blue spaces is a crucial parameter to increase the cooling efficiency.

[17] 'e.g. http://www.es.lancs.ac.uk/cnhgroup/download.html

From epidemiological studies on the relationships of nature with human health it is known that green areas can ameliorate particular diseases either through reductions in air pollution or the positive effects on mental stress. The PHENOTYPE project, for instance, focussed on quantitative and qualitative characteristics of the natural environment to assess the effects on various aspects of human health using a combination of methods. One of the important findings was a reduction of the risk of cardiovascular disease mortality in areas with higher residential greenness despite no evident benefits emerged for lung cancer mortality (Gascon et al., 2016). Moreover, air pollution concentrations were associated to important reductions in life expectancy particularly in relation to PM2.5, PM10, O3 and NO2. A protective effect of green areas on mortality and longer life expectancy was only found in areas with lower socioeconomic status (De Keijzer et al., 2017).

However, due to the complexity of situations and the difficulties in conducting epidemiological studies, it emerged that in few particular cases the role of urban trees on particular diseases such as asthma might even be negative, as highlighted in a recent review carried out in the framework of the ISOSCAPE project in collaboration with North American universities (Eisenman et al., 2019).

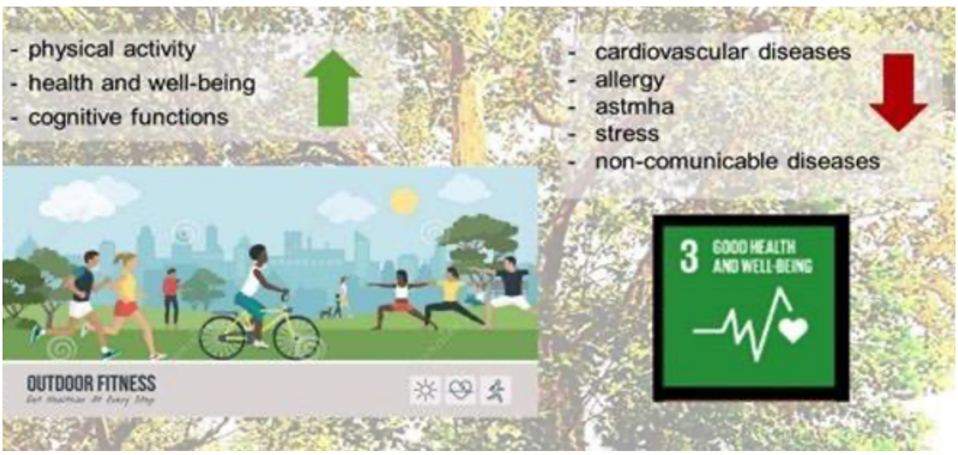


Figure 33. Benefits of NBS on Health and Well-Being (corresponding to Sustainable Development Goal n. 3). Green arrow refers to scientifically demonstrated increase, red arrow refers to scientifically demonstrated decrease. More details in the text. Image: C. Baldacchini

The issue of respiratory diseases is also related to the allergenicity potential of certain plant species. In a number of projects such as GREENINURBS this aspect has been studied while also carrying out a characterization of allergenic sources from urban areas and its implications (Carinanos et al., 2016). This aspect is also included in the Specifind tool for the choice of plant species presented in Figure 32.

The effect of green areas on mental health and cognitive development of children has been also studied (see Table 24). Dadvand et al. (2015) observed enhanced 12-month progress in working memory and a reduction in inattentiveness associated with greenness surrounding schools and the living areas. Interestingly, traffic-related air pollution also explained part of the associations between school greenness and children cognitive development. Even the brain development of new-born babies seems to be quicker if in contact with green areas (Dadvand et al., 2019). Studies also showed stress reduction as people walk into urban green spaces using wearable sensors to detect brain activity and electroencephalogram-based emotion recognition software for functional brain imaging (Aspinall et al., 2015).

Healthy corridors are also being developed within the URBINAT project, based on a customised NBS catalogue, with a particular focus on deprived districts using an innovative and inclusive urban model and linking social housing neighbourhoods.

Recently Biodiversa has launched a call on 'biodiversity and its influence on animal, human and plant health'; in particular, two projects are about to start (ANTIVERSA and Dr. FOREST) with a focus on the role of NBS on human health and well-being[18].

TABLE 24: Effect of exposure to green and blue spaces on human heath indicators as compared to urban environment from a number of case studies in Catalonia

PSYCHO-PHYSIOLOGICAL INDICATORS	GREEN SPACES	BLUE SPACES
Total Mood Disturbance (TMD)	-	-
Attention capacity – backwards digit-span task (BDSP)	(-)	=
Salivary cortisol	(-)	-
Blood pressure		
- Systolic	-/+	(-)
- Diastolic	+	-/+
Heart rate	-/+	-/+

Notes: Sign + and – represent significant positive or negative effects, sign in parenthesis represent a tendency but not a significant effect, = represents no effect, -/+ represents a great variability of responses from the different case studies. Source: PHENOTYPE project and Triguero-Mas et al., 2017

[18] https://www.biodiversa.org/1643

More recently a report of the EKLIPSE Expert Working Group on Biodiversity and Mental Health provides recommendations for the conservation, planning, design, and management of urban green and blue infrastructures (EKLIPSE, undated).

Unfortunately, the direct impact of NBS on health is sometimes difficult to determine either because large scale implementation is needed to detect significant effects and because it is not easy to directly link people's life with the implemented NBS, either in spatial and temporal terms.

It has been generally observed, as evidenced in the NATURVATION project that in order to understand the impact and the effectiveness of NBS you should rely on indicators of satisfaction or well-being measured at neighbourhood level. This is for instance what is also being done in the project PROGIREG, which is investing a considerable amount of time with questionnaires to various individuals in the areas near the implemented NBS or in control areas.

7.3. POLICY RECOMMENDATIONS AND RESEARCH GAPS

- Assessing the nexus between health and climate, energy, food, bioeconomy, agriculture and environment for biodiversity is crucial in order to develop innovative solutions for addressing complex, interlinked challenges.

- Air quality and heatwaves generate high risks for human health with implications on the insurance industry. User-friendly valuation tools for the evaluation of risk reduction by using urban NBS should be developed. It would be important to understand how this evidence can be used to carry out investment ratings and to price the risk value of urban NBS.

- Using NBS across the urban-rural gradient offers a unique opportunity to study the effect of the urban conditions on the selected plants and at the same time offers the possibility to understand the impact on the air pollution and UHI mitigation potential of those plants and their ecosystem services provision.

- Unfortunately, too often NBS are implemented by cities for air quality or UHI without an accurate preliminary study. Due to the fact that NBS are often implemented within dense urban infrastructure, they could be too small to have a significant impact on environmental quality. Such small and fragmented NBS should be at least connected to green corridors to maximize their impact on biodiversity and other environmental goods.

- Sustainable NBS must be safe, durable and resilient to extreme weather events, including heat waves and pollution peaks, windstorms, excessive precipitation and drought. So far, most projects have investigated the effects of NBS on microclimate, while the susceptibility of NBS to extreme events has been neglected and requires further research.

- Air quality is still a major challenge to European citizens' health, in particular because of particle and ozone pollution. Serious knowledge gaps still exist about the species-specific and NBS-specific particle and ozone forming potentials and capacity of pollution uptake.

- The links between air pollution mitigation and human health are not yet clear and conclusions tend to vary from study to study. The main difficulties relate to the lifestyle of the selected people, including the proximity to NBS. Furthermore, the relationships addressed by epidemiological studies are often characterized by high variability. It is therefore important to conduct more interdisciplinary studies with robust case studies collecting data from numerous individuals.

- Even if it is recognized that reducing UHI can decrease energy costs and above all the carbon footprint at urban level, there are very few studies (with those being mainly from outside Europe) which try to estimate how much this contributes to the carbon savings either at local, city or regional level. Such assessments are essential to measure their contribution to the EU goal to become carbon-neutral by 2050.

- The numerous regulatory gaps, both in the EU and in Member States' legislations limits the application of phytotechnologies as remediation techniques and the valorisation of the biomass produced. An open debate among administrative bodies, research institutions and stakeholders is the basic and crucial starting point for the implementation of a regulatory framework in this field.

- More research is needed to estimate the particle-forming potential (plants emit species-specific volatile compounds that act as aerosol precursors), ozone forming potential (the same volatiles stimulate O3 formation and emission factors are missing for a huge number of species) and capacity of pollution uptake (data and models) for different plant species and plant-assembled NBS.

- 'The best species in the best place' is a successful motto but is not substantiated by research results especially considering the changing climate, social and economic scenarios. Planning and maintenance of NBS will need to rely on ambitious selection programs similarly to what is done for agricultural varieties in order to increase the potential benefits on human health and well-being and considering the mitigation capacity both in terms of air quality and urban heat island effect.

Nature-based Solutions towards sustainable communities

Harriet Bulkeley

8. NBS: TOWARDS SUSTAINABLE COMMUNITIES

8.1. INTRODUCTION: EU POLICY GOALS AND THE POTENTIAL OF NBS

Ever since the EU's Fourth Environmental Action Programme 1988 – 1992 sustainable communities have been central to the ways in which the European Union and its member states have sought to address global and local sustainability challenges. In 1992 Agenda 21, an international agreement reached at the Rio Earth Summit, included a specific Chapter calling for the development and implementation of Local Agenda 21 in cities and towns globally (UN, 1992). Over the past thirty years local communities have remained at the heart of efforts to address sustainable development, mobilised by a wide range of policies and initiatives to develop sustainable, smart, low carbon, resilient and eco-cities. The adoption by the international community in 2016 of the New Urban Agenda (UN, 2017) and SDGs has given new impetus to the importance of ensuring sustainable communities.

In addition to requiring national governments to work individually and collectively towards a goal for Sustainable Cities and Communities (SDG11), the SDGs have pointed to both the interconnected nature of sustainable development and the importance of cities and communities in realising multiple global outcomes (Nilsson et al., 2018). Within the EU, the Urban Agenda was agreed in 2016 as a means through which to develop a "multi-level working method promoting cooperation between Member States, cities, the EC and other stakeholders in order to stimulate growth, liveability and innovation in the cities of Europe and to identify and successfully tackle social challenges" (EU, 2020). The Urban Agenda covers a wide range of topics, from housing and the inclusion of migrants and refugees in local communities, through to issues related to local economic development, poverty and the digital transition - pointing to the complexity and interwoven nature of the challenge of sustainable communities.

As well as gaining prominence in its own right, this focus on cities and communities is also to be found in the increasingly converging international agendas for urgent action on climate change and biodiversity. For example, the IPCC 1.5 Degree Special Report "identifies cities and urban areas as one of four critical global systems that can accelerate and upscale climate action" (Bazaz et al., 2018). Likewise, the recent IPBES Global Assessment Summary for Policy Makers identified land-use change resulting from urbanisation as the major driver of biodiversity decline as well as noting the significance of cities and communities in shaping the underlying drivers of the global loss of nature through the forms of consumption and values that they foster (Diaz et al., 2019).

The pursuit of sustainable communities is therefore now positioned as central to the interconnected challenges of urbanisation and global sustainability objectives. At the local level, policies and initiatives increasingly emphasise the ways in which pursuing goals for air pollution, climate change and reducing waste, are connected to improving the quality of life and livelihoods in particular places. NBS have found fertile ground in this new focus on the interconnected nature of urban sustainability challenges. As interventions that promise to simultaneously address multiple goals and to provide a wide range of environmental, economic and social benefits, NBS are ideally positioned for those actors who are seeking responses to sustainability challenges that resonate at a local level whilst also addressing global issues. In short, NBS are increasingly being seen as a means through which it is possible to generate sustainable communities whilst also attending to other challenges – such as biodiversity, climate, and air quality as addressed in other sections of this report.

It is not only the resonance of NBS with the increased focus on the interconnected nature of sustainable development goals that has attracted attention. In addition, NBS are also seen to have the potential to offer a transformative approach for meeting sustainability challenges, as discussed in detail in section 9.

While there remains significant debate about what transformative action for sustainability might entail, at the heart of this debate are concerns for ensuring that the processes through which sustainable communities are designed, strategies formulated and initiatives implemented are inclusive and that the outcomes of such designs, strategies and interventions are transformative not only in environmental terms but also account for issues of social justice. Evidence suggests that NBS can, and indeed often do require, new processes for design and implementation that are by their very character more inclusive and that they are able to provide outcomes that are transformative for nature, people and place. At the same time, there is also a growing body of research that suggests that NBS can exacerbate inequalities and generate outcomes that are incompatible with goals for sustainable communities.

This part of the report examines how NBS can contribute to transformative action for sustainable communities, whilst the following section 9 turns to the question of how the governing of NBS is taking place and its implications for public, private and civil society actors. Here, the focus is first on the ways in which such initiatives enable participation and inclusion in the design and implementation of sustainability at the local level and second on the extent to which the outcomes of NBS are transformative for communities. This section then turns to consider the challenges and opportunities documented across the different projects and initiatives for realising sustainable communities through NBS, before identifying gaps and recommendations for future research and policy.

8.2. CO-CREATING SUSTAINABLE COMMUNITIES WITH NBS?

Across the wealth of evidence that has been generated through projects funded by FP7 and H2020 about the potential value of NBS for sustainable communities there is almost universal agreement that such initiatives can and should allow for the involvement of local communities in their design and implementation. Nonetheless, there are diverse perspectives on what such involvement should entail, what it should be designed to accomplish and what kinds of community involvement arise as a result (Figure 34). As PROGIREG research suggests "there are different levels and thus gradients" of involvement taking place in NBS, from one-way processes of providing information to stakeholders and members of the public to "consult, involve, partner and empower" modes, which shift control away from municipal authorities who are most often the initiators of such projects towards stakeholder and community groups (Hanania & Anton, 2019). Across this variety of approaches, three different though not mutually exclusive perspectives can be identified:

- First, research has emphasised the value of involving stakeholders and communities in NBS as a means of increasing their knowledge about and action towards urban sustainability. These approaches tend to emphasise the importance of open and transparent planning processes and institutionalised forms of participation.

- Second, there is a growing emphasis on the importance of various different kinds of co-production processes in the design, development and implementation of NBS as a means through which relevant knowledge and experience from diverse actors can be harnessed towards creating sustainable communities. Here the focus tends to be on the need to design novel settings and processes – such as urban living labs or transdisciplinary co-creation methods – within which actors can be engaged to generate new outcomes for specific places.

- Third, attention is now turning to questions of how NBS may serve to sustain or challenge issues of inequity in urban planning and development processes, and whether alternative means of participation can overcome long-standing issues of exclusion. Research suggests that this is unlikely to be possible within the frameworks of existing institutions or through the careful design of new processes, but must necessarily also allow for forms of contestation and conflict.

POTENTIAL ROLES FOR CIVIL SOCIETY IN SUSTAINABILITY TRANSITIONS

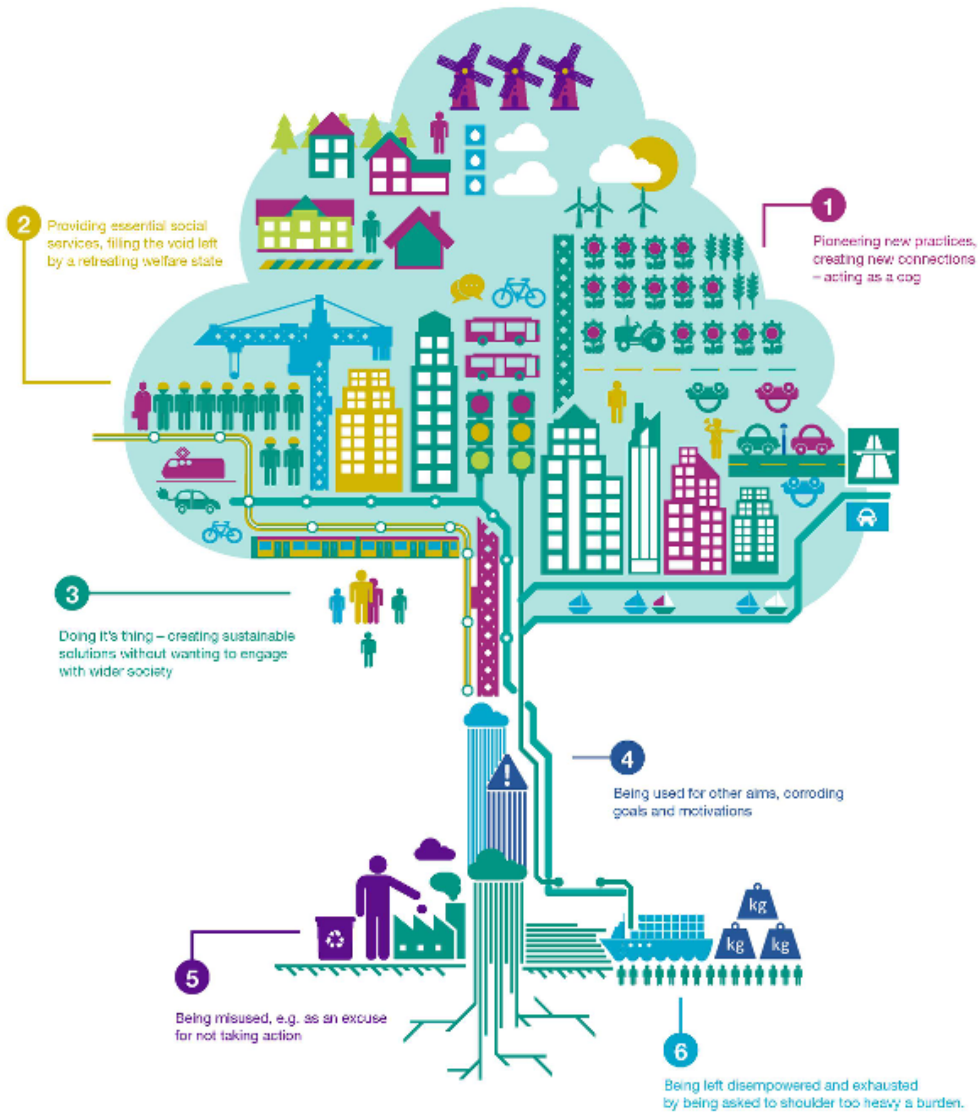


Figure 34. Roles for Civil Society in Sustainability Transitions identified by the ARTS project.

8.3. CULTIVATING KNOWLEDGE & ACTION

Historically, a good deal of emphasis has been placed on the ways in which well-designed processes of stakeholder and public engagement can be used to inform or educate, with the intention of fostering acceptance of public policies or active engagement in their implementation. Such a perspective is rooted in an understanding that the most important barriers to participation and action lie in relation to information and knowledge, and seek to overcome these issues by providing stakeholders and the public with more understanding about the benefits of urban NBS. Such approaches were found in the RESIN project to be important in fostering sustainable, resilient communities by building stakeholder knowledge and fostering new relationships and trust between municipal authorities and stakeholders (Chapman et al., 2018).

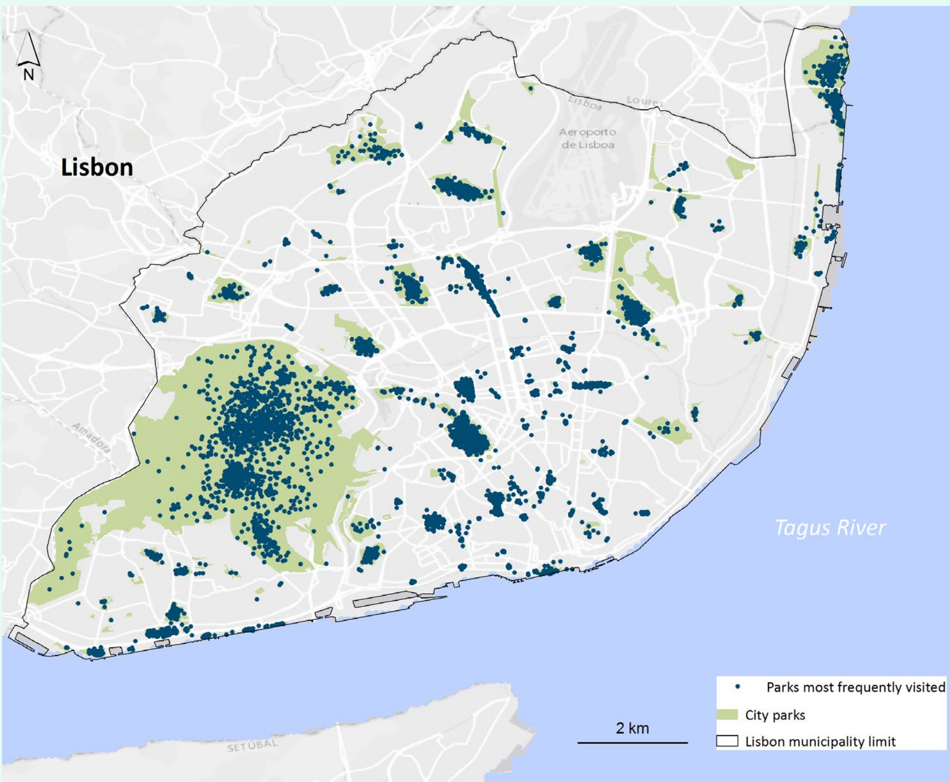
To enhance and develop public knowledge about urban nature, several NBS projects have sought to deploy different forms of citizen science. This involves the design of processes for data collection and analysis that actively engage citizens and seek to improve their awareness. Such actions are frequently taken by knowledge and cultural institutions. For example, the Bristol Natural History Consortium, a group involving local wildlife organisations, businesses and the city council, organises what are called 'BioBlitz' events to generate data on local biodiversity through using citizen science as well as organising an annual Festival of Nature to engage the public (Hansen et al. 2015: 67).

UNALAB has found that the development of 'citizen platforms' through which such data can be stored and shared can also prove to be a valuable resource for increasing citizen awareness of the value of urban nature and their engagement with initiatives to protect and restore urban nature (Hawxwell et al., 2018: 52). Furthermore, as GREEN SURGE found, such techniques are not only useful for informing citizens about urban nature, but can also lead to improvements in urban planning outcomes. The project found that Public Participation GIS tools provide a suite of options that can be used at different stages of the planning process to support planners in "making better decisions about land-use, management and resource allocation" and supporting greater citizen "involvement in assessing and planning urban green spaces, e.g., through mapping the uses of such spaces, their perceived environmental quality or ecosystem services" (Hansen et al., 2017: 40).

BOX 54. NEW TOOLS FOR PUBLIC PARTICIPATION

The GREEN SURGE project conducted a Public Participation GIS (PPGIS) survey in Lisbon, Portugal, in 2017, in order to support local planning processes for Urban Green Infrastructure (Hansen et al. 2017). The survey focused on which green spaces were visited and avoided and which were perceived to have high levels of cultural diversity or biodiversity. The project concluded that PPGIS had the following advantages for promoting public participation:

1. Enables many residents and stakeholders to more easily participate in planning processes, especially those without the time or confidence to attend traditional forums.
2. Can promote dynamic interaction between stakeholders.
3. Is relatively inexpensive and easy to conduct.
4. Offers maps as a tangible outcome to support planning and management decisions



8.4. HARNESSING KNOWLEDGE FOR SUSTAINABILITY TRANSITIONS

A second and increasingly common strategy for engaging stakeholders and communities in the design and ongoing implementation of NBS involve what are variously termed co-production, co-creation or transdisciplinary approaches.

As discussed in section 9, such approaches form one of the main modes of governing NBS that have emerged in European cities. Here, rather than participation being seen as a means to generate increased knowledge or action in relation to nature, it is regarded as an essential element of how strategies and initiatives are designed and sustained over time through ensuring that relevant stakeholders and communities feel a sense of ownership over the process and outcomes delivered.

Over the past decade there has been an upward trend in the use of such approaches, with the result that "numerous projects and interventions have been set up to facilitate participatory and collaborative processes that aim to integrate different ways of knowing and jointly develop knowledge that is actionable and that contributes to effective and legitimate solutions and the transformation of society" (Turnhout et al., 2020: 15). In part, this trend is linked to changing cultures of knowledge production within the research and higher education, but it also emerges in light of the increasing acknowledgement of the 'wicked' nature of sustainability challenges where their complexity requires that many and varied forms of knowledge, capacity and authority are bought to bear in their resolution.

The growing interest in co-production and co-creation as means through which to achieve sustainable communities is emerging at least in part from the recognition that local authorities need to involve other "creative and capable" actors such as businesses and communities if they are to successfully govern sustainability challenges (Frantzeskaki, 2019: 106), but also in recognition that where governance processes are opened up to these actors they are more likely to take an active role in their resolution. As the PHUSICOS project suggest "including stakeholders in the design and application of NBS … can increase acceptance among stakeholders by promoting understanding and visibility of the concept while bringing additional normative benefits by improving the democratic nature of the process and therefore its acceptance" amongst those involved (Fohlmeister et al., 2019: 28).

8.4.1. Establishing new communities of practice

Some forms of co-production and co-creation focus primarily on establishing new communities of knowledge and practice through partnerships between municipal authorities, research institutions and stakeholders. As documented by the PATHWAYS project these initiatives are often rooted in transformative science, "a specific type of science that does not only observe and describe societal transformation processes, but rather initiates and catalyses them" (Berg et al., 2016: 5) and take two main forms – Real World Experiments or Sustainable Living Laboratories. Real World Experiments work with existing practices and initiatives but seek to bring together new actors and means through which to further develop and learn from such initiatives in real-time, whereas Living Labs are usually designed from the outset as collaborative, learning spaces where at least the intention is to design in forms of monitoring, reflection and adaptive learning from the outset. Such arenas are found to be valuable within the ARTS project because they create the "spaces to interact, debate, connect and experiment with other innovators and resourceful actors of the city" that are necessary for initiatives that aspire transitions towards sustainability to flourish (Gorrison et al., 2017: 12).

Such new institutional spaces they found need to "to be open and to be facilitated in a flexible way, to tap into the current developments of the city and to be left as democratic spaces of sustainability: transparent, self-organised and open" and could be successfully convened either by local authorities, intermediary organisations of transition initiatives themselves (Gorrison et al., 2017: 12).

While such 'safe spaces' for experimentation have been found to be important for all forms of sustainability transition, they may be particularly important in relation to NBS where the benefits generated accrue to a wide range of public and private stakeholders and where existing approaches for providing grey infrastructure and services in cities are 'locked in' across multiple institutions, forms of practice and evaluation. For example, the PEARL project found that stakeholder engagement is a vital way of ensuring greater understanding and uptake of information (PEARL, 2014:2) whilst results from OPERANDUM suggest that a "participatory process contributes positively in leveraging the widest possible level of NBS acceptance and promote its use as a good practice" (Soini et al., 2019: 12).

8.4.2. Building participatory approaches

Besides their central ambition to foster collaboration between research, policy and practice, some forms of co-creation and co-production have a much stronger focus on working with local communities. As research from the OPENNESS project points out, participatory local planning and approaches that seek to co-design interventions with communities can strength joint decision-making and generate "co-ownership, higher public support, a higher likelihood of implementation" and are "likely to save time in the long run" (OpenNESS, 2017: 1). They further suggest that "implementation of such plans increases the chances to obtain more sustainable outcomes and enhanced societal well-being" (OpenNESS, 2017: 1).

Indeed, the NAIAD project found that such forms of engagement and co-production in their demonstration sites in the Lower Danube and in Slovenia found that the development and deployment of a 'community-based monitoring system' enhanced both the knowledge and participation of local stakeholders. It was found that the whole process "co-definition of benefits and co-benefits, indicators definition and [community-based monitoring system] design – contributed to make the involved stakeholders aware of the wide range of benefits that can be produced through the NBS implementation" (Giordano et al., 2019).

8.4.3. Limited implementation

In short, co-design and co-production approaches are thought to be valuable ways of working with communities not only because they provide more transparent, inclusive and effective processes for developing sustainable communities, but also because they have been found to lead to better outcomes (Haase et al., 2017; Frantzeskaki, 2019). Yet implementing such approaches has been found to be highly challenging. For some, the central issues arise in terms of how co-production processes are designed and run. The CLEVER CITIES project finds for example that greater public participation "can be fostered by: maximizing the flow of targeted information to stakeholder groups and organizing consultations, workshops and opportunities for feedback and communicating the multi-functionality of NBS to increase awareness and support" (Schmalzbauer, 2018).

Likewise, the OPENNESS project draws attention to the importance of ensuring that the scope, mandate and purpose of any co-design process are clear from the outset, and that while the relevant stakeholders should be involved from the outset it is important to design a flexible process that can adapt to the changing context and needs of participants (OpenNESS, 2017). Yet others have found that despite effective and careful planning and design, co-production processes are still challenging to implement and can indeed be problematic in terms of both the processes and outcomes they deliver (Figure 35).

TICK-THE-BOX CONSULTATION CULTURE
Ironically 'bottom-up' citizen consultation is increasingly being forced 'top-down' on local governments by international funding bodies without due recognition of the lack of knowledge, experience and belief in citizen consultation at local level. This is leading to a counter-productive 'tick-the-box" consultation culture.
ENGAGING THE USUAL SUSPECTS
A fall out from the 'tick-the-box' consultation culture is an over-reliance on the same citizens and stakeholder groups in co-creation processes. When it's always the same voices at the table, this leads to stakeholder fatigue on one hand and lack of genuine stakeholder representation on the other.
TIME PRESSURE
Co-creation takes time to do right. Unfortunately for many cities coping with the impacts of natural disasters or major population inflows there is intense political and public pressure to deliver solutions within short timeframes.
UNREALISTIC EXPECTATIONS
Local government and private developers alike are wary that citizen consultation will lead to unrealistic expectations of what is possible within limited budgets. Indeed very often the business and finance communities are not equally engaged in the co-creation processes.

LACK OF TRUST IN GOVERNMENTS
Citizens living in highly uncertain or divisive political environments have lower levels of trust in their political representatives and are reluctant to engage in what may be perceived as political manoeuvring.
ECONOMIC HARDSHIP
Lower-income citizens highly affected by public sector cutbacks in basic services like health or housing are also difficult to engage in co-creation exercises displaying a range of attitudes from anger to apathy, ignorance to scepticism.
ELITISM
For many years, 'green' sensibilities were perceived as a middle-class preserve. While few would fall into the category of climate change deniers, for many working class areas climate change and biodiversity measures were simply not a priority leading to a general sense of civic inertia to co-creating such measures.

Figure 35. Challenges of Participation in NBS identified in CONNECTING NATURE (2019)

8.5. ADDRESSING CHALLENGES OF EXCLUSION & INEQUITY IN PARTICIPATION PROCESSES

As discussed above, across the range of initiatives and projects that are taking place to develop NBS, primarily in urban communities, explicit attention is given to how to involve groups such as refugees, young people and women who are often excluded from urban design and planning. In this way, NBS have proven to be an effective means through which to build processes and practices for sustainable communities, with a whole host of new tools and techniques being trialled, scaled up and shared as a result. As detailed above, there is extensive evidence of these practices at work across the portfolio of projects supported by EU finding over the past decade as well as across a whole host of initiatives that have been documented in Europe and beyond by this research effort.

Yet there is now widespread acknowledgement that the presence of participatory or co-design processes should not automatically be considered as a means through which social inclusion can be fostered. As CLEVER CITIES suggest challenges of inclusion arise because "the interests of groups like women, ethnic minorities or disabled people might not be given equal consideration and some citizens might not have access to standard participation tools" (Schmalzbauer, 2018). To address this, approaches which specifically target groups with less power in policy systems and seek to either lower the barriers for participation or to increase capacity are usually suggested (Hansen et al., 2017; Schmalzbauer, 2018). For example, GREEN SURGE found that to increase participation amongst those who are often marginalised it is necessary to deal with barriers that arise including a "lack of financial and human resources, time constraints, insufficient representation of interest groups, lack of social facilitation skills among city officials and/or non-governmental actors, or the limitations of policy frameworks" (Hansen et al., 2017: 41).

Despite the good practice that is evident across many different projects and initiatives, research suggests that more fundamental questions of politics that arise through efforts to engage highly diverse urban communities in the development of NBS are usually overlooked. For the most part, where efforts are directed towards increasing participation and inclusion in the co-design and implementation of NBS, the assumption is one of working towards consensus and minimising conflict (Turnhout et al., 2019; Anguelovski et al., 2018).

However, more critical research warns that we must also consider the ways in which interventions designed to 'green' cities can have a detrimental effect on issues of equity and inclusion (Haase et al., 2017). The GREENLULUs project suggests that research and practice in this field has to date not engaged sufficiently with the "deeper question of who has the right to a green city, and how 'secure' this right is over the long term" (Anguelovski et al., 2018).

In short, while there are increasing efforts to ensure that underrepresented and marginalised groups are actively included in processes of participation for the design, development and management of NBS without considerations of who is benefiting from the outcomes of such processes there is a danger that such forms of participation may themselves be exploitative, providing justification for projects that in the longer term either provide little contribution to the kinds of sustainability that such communities need or desire. Even more starkly, where such issues are not considered, even proactive and progressive processes for social inclusion may serve to undermine such outcomes being achieved by lending legitimacy to projects which actually serve to deepen or widen social inequality, as we discuss further below.

8.6. IMPROVING THE QUALITY OF LIFE

The majority of projects and initiatives seeking to design and implement NBS identify their contribution to social well-being and an improved quality of life as one of the key outcomes that such interventions can deliver. The WHO define quality of life "as an individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns" and go on to recognise that this "is a broad ranging concept affected in a complex way by the person's physical health, psychological state, personal beliefs, social relationships and their relationship to salient features of their environment" (WHO, 2020). There is then no one formulation of the quality of life or the means through which it might be improved.

Similarly when it comes to well-being, though it is commonly thought to encompass physical, mental and emotional health, definitions of what constitutes well-being and how it can be improved are often broad and vary in scope. Nonetheless, a now extensive evidence base collected over the past two decades has demonstrated that the provision of urban green space has direct benefits for both well-being and quality of life, through, for example, promoting physical activity, reducing stress, providing spiritual connection, creating senses of place and community and providing havens for escaping the strains of daily life in the city (see section 7; Cooper, 2017; Kabisch et al., 2016c; WHO, 2016).

Yet, as discussed above, with the realisation that nature generates benefits for individuals and communities has come a concern that access to such benefits is highly differentiated. This section considers how different forms of social and cultural benefit that contribute to sustainable communities through enhancing social well-being and the quality of life are generated through NBS, before turning to consider particular forms of intervention that are proving to be particularly significant in ensuring that such benefits reach those who are currently excluded.

BOX 55. CONNECTING NATURE: GROWING SOCIAL COHESION

The largest park in the city, Glasgow's Pollock Country Park is a site of rich natural and cultural heritage containing extensive gardens and woodland areas. In response to the dramatic loss of Britain's wildflower habitat, Flower Power was established through a collaboration between Glasgow City Council park rangers, TCV Scotland and Grow Wild. Growing over 10,000 locally-sourced, native wildflowers for parks, green spaces and community projects across the city, this NBS also places generating social cohesion at its heart. The project offers volunteering opportunities, education and training for participants, whilst also providing a means through which to sustain biodiversity in the city.

8.7. NATURE'S CONTRIBUTION TO PEOPLE

That nature provides social and cultural benefits has long been recognised within the literature on ecosystem services, which views such services as being able to give rise to a "positive change in wellbeing from the fulfilment of needs and wants" (Maes et al., 2013: 48). More recently, the ways in which nature is seen to benefit society has been broadened through the notion of 'nature's contribution to people' (IPBES Global Assessment) a broad heading that seeks to take account of both the direct services that natural systems generate that then come to produce benefits as well as the values that nature comes to hold and embody for society.

BOX 56. INTEGRATING NEIGHBOURHOOD GREEN SPACES FOR RECREATION

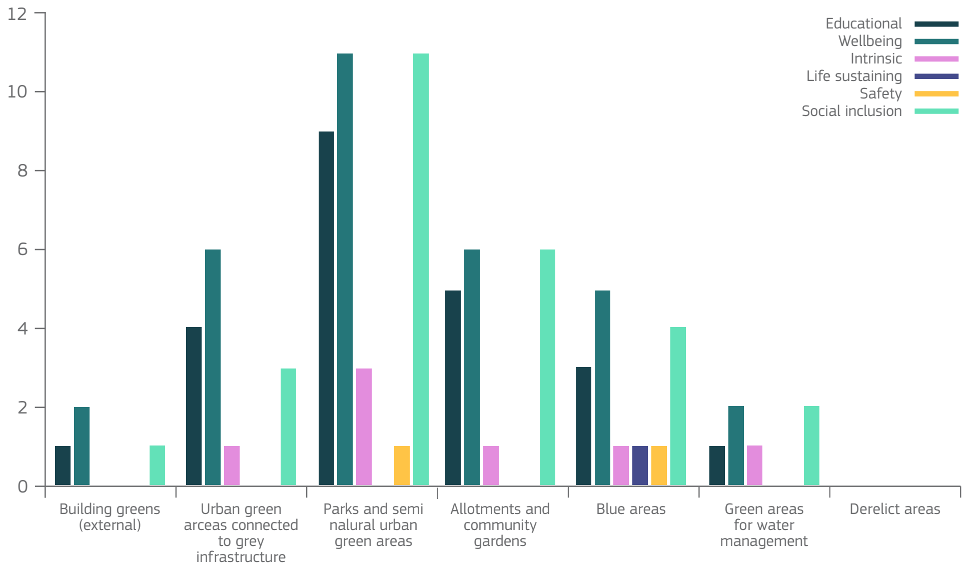
In parallel to the development of large parks and reconstruction projects, Valencia has built an extensive network of a small gardens and neighbourhood parks creating almost 100 ha of space for recreation that are woven through the city's neighbourhoods. These include the Parque de la Alquería de Ricós (where since 2003 1.9 ha of landscaping have surrounded a pedestrianized street). These spaces provide important opportunities for recreation and neighbourhood gatherings, especially for children and elderly people, enhancing accessibility to nature and well-being.

Source: http://www.bcnuej.org/wp-content/uploads/2018/06/Green-Trajectories.pdf

We can understand the values of nature as either those which are 'held' and might relate to a particular condition, such as freedom, or quality, for example beauty, as well as those which are 'assigned' by individuals in particular circumstances, such as worth or monetary value. Benefits in turn relate to the impacts of such values – how values are realised for particular communities, people or places at a given moment – and can be either directly economic, or take the form of a change in how people's wants and needs are met.

While it has been primarily the benefits that nature produces that have been seen as contributing to well-being and improving the quality of life, the expanded focus on 'nature's contribution to people' directs us to consider also the ways in which NBS contribute to existing values or indeed can lead to a change in held or assigned values as an important means through which well-being and the quality of life can be enhanced (Diaz et al., 2019; da Rocha et al., 2017).

In a meta-review of just under 100 research papers (da Rocha et al., 2017), the NATURVATION project found that evidence related to the social and cultural values and benefits of NBS has focused on urban parks, followed by the generic category of green space and then community gardens and blue infrastructure. This evidence base has tended to focus on cultural values, with a concentration on how NBS contribute to aesthetics, with those studies of social values demonstrating that NBS contributed to educational values and social interaction. The social benefits of NBS were found to be primarily related to health and social interaction, whereas in cultural terms there was a focus on recreation (Figures 36 & 37).



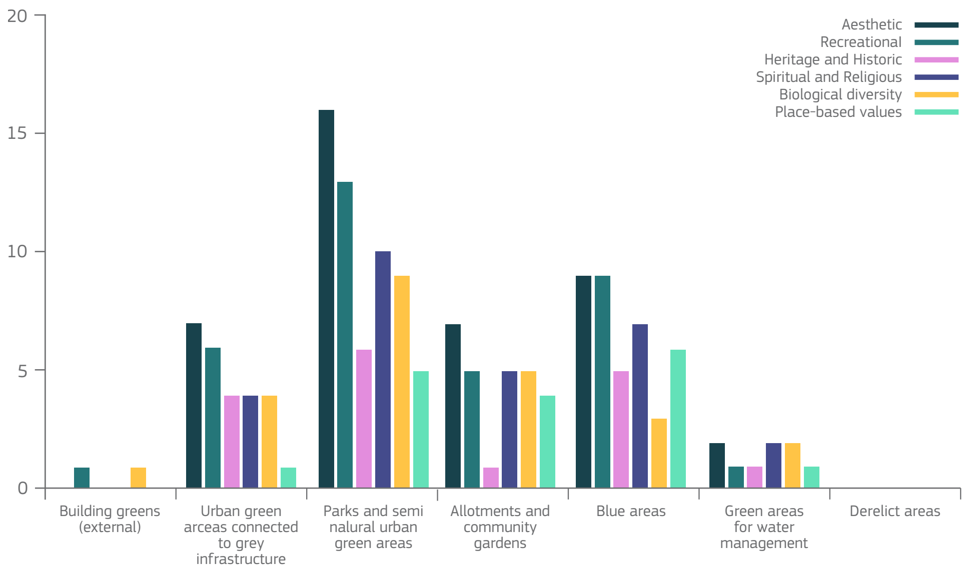
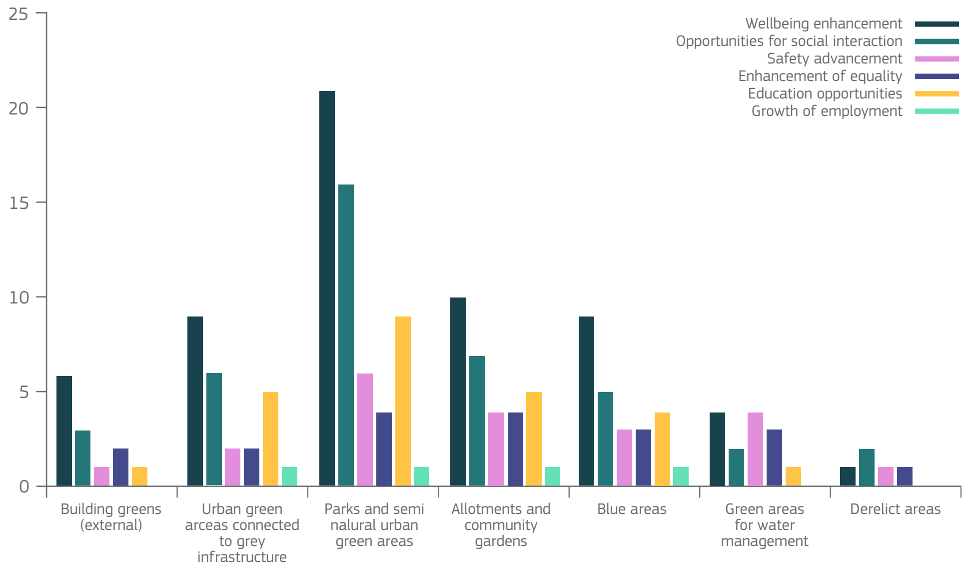


Figure 36. No. of studies of social & cultural values associated with different NBS (da Rocha et al., 2017)



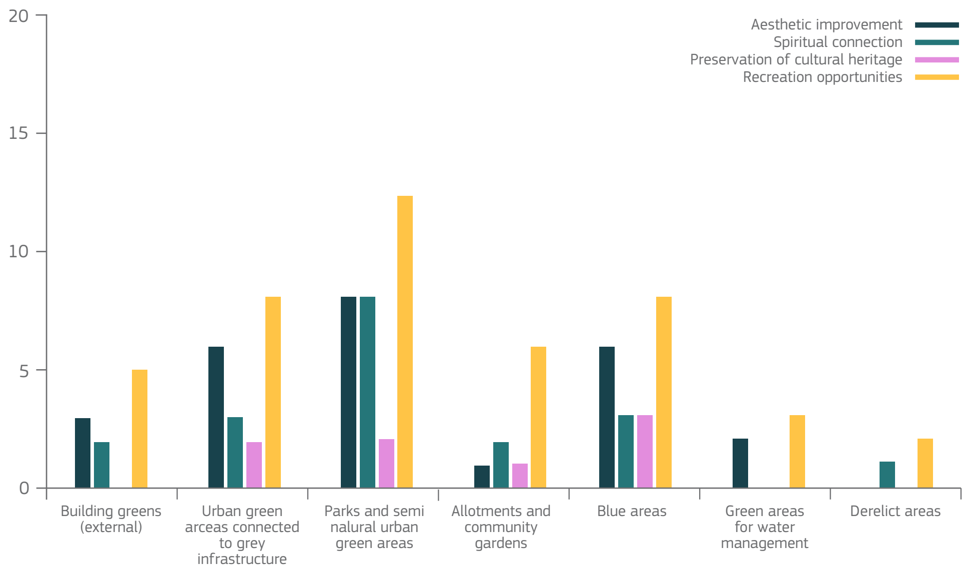


Figure 37. No. of studies of social & cultural benefits associated with different NBS (da Rocha et al., 2017)

However, as results from the GREEN SURGE project remind us, the ways in which social and cultural values and benefits are realised through urban nature is highly diverse. Developing the concept of biocultural diversity the project developed a framework through which to understand intrinsically linked human-nature relations as consisting of three dimensions: lived everyday practices and experiences of interacting with nature; materialized in terms of the physical and discursive form that these nature-society relations then take, whether it be in the layout of parks or the planting of community gardens, through to the policies, plans and assessment frameworks through which they come to be understood; and stewardship which refers to the forms of engagement through which individuals and communities come to take responsibility for the design and management of urban green areas (Pauleit et al., 2019: 10).

Applying this framework they found that "people largely prefer high plant species richness in parks, wastelands, and streetscapes and believe that high biodiversity supports more liveable cities" but also that "considerable variation existed among cities and sociocultural groups" both in terms of their values as well as in terms of their practices within green space (Pauleit et al., 2019: 10). Furthermore, studying community gardens the project found that such sites did offer "places for engagement and social cohesion" as a result of the kinds of stewardship that were fostered but that this could create feelings of protection which hindered the participation of other social groups, in terms leading to a decline in social cohesion at the neighbourhood level (Pauleit et al., 2019: 10).

BOX 57. FOSTERING BIOCULTURAL DIVERSITY

In Malmo, the GREEN SURGE project identified the development of new urban gardening spaces in parks and residential areas as important sites of biocultural diversity. These new gardening spaces complement historic allotment gardens and allow local citizen's interests in interacting with biodiversity to be recognised and cultivated. Similarly, the recent development of diverse urban biotopes such as wetlands have provided resources for teaching and learning across diverse communities about the value of biodiversity and ecological services.

8.8. TACKLING THE UNDERLYING DRIVERS OF INEQUALITY?

If there is now strong evidence that NBS can effectively contribute to improving well-being and quality of life, there is also a growing concern that not only are such contributions unevenly distributed but also that such interventions may serve to entrench or exacerbate existing social inequalities.

First, there is growing evidence to support the concern that NBS tend to be located within areas of cities with higher socio-economic status and where wellbeing and quality of life are already high (Anguelovski et al., 2019; Kabisch et al., 2016c). As discussed above, increasingly NBS are designed and implemented with the involvement of communities but tend to involve the 'usual suspects' and run the risk of creating new forms of social exclusion that serve to entrench existing patterns of access to urban nature.

While much of this debate focuses on how to change processes and patterns of participation, there has to date been less discussion about what it might mean to ensure that NBS are installed and embedded in those neighbourhoods which have historically had less access to nature and where their value in terms of well-being and quality of life may be significant. This may involve, for example, shifting our understanding of what constitutes a 'good' or 'appropriate' form of NBS.

As the GREENLULUs project has found, typical interventions for urban greening such as large parks which are known to deliver strong benefits in terms of e.g. water retention, cooling or biodiversity benefits may be negatively associated with issues of risk or exclusion for ethnic minority or refugee populations in a city and may not generate the kinds of benefits for well-being and quality of life that they are seeking (Anguelovski et al., 2018). This suggests that ensuring that NBS do not simply reproduce existing patterns of inequality in terms of participation in and access to urban nature will require an openness to reconsidering what appropriate NBS are in different neighbourhoods and for different communities.

Second, by generating increased value for urban sites and neighbourhoods, research has shown how NBS can contribute to the phenomenon of green gentrification in which households and communities that inhabit areas of cities targeted for development or regeneration find themselves priced out of the housing market or excluded from accessing green spaces or other forms of NBS that have been created for the private use of new residents or businesses (Haase et al., 2017; Hawxwell et al., 2018).

In particular, research undertaken by the GREENLULUs project finds that "green amenities become GreenLULUs (Locally Unwanted Land Uses) and socially vulnerable residents and community groups … become excluded from new green amenities they long fought for as part of an environmental justice agenda" (Anguelovski et al., 2018: 419). Many NBS are being designed and implemented as projects for urban improvement which seek to improve the economic quality of urban areas, often with good intentions but which serve to consolidate an urban sustainability and redevelopment strategy that sees urban greening primarily in terms of marketing new urban spaces and which prevents a "deeper reflection on urban segregation, social hierarchies, racial inequalities, and green privilege" (Anguelovski et al., 2018: 417). At the same time, NBS can find themselves subject to development pressure as urban land prices rise and existing green spaces come to be seen as prime land for housing or businesses. Research by NATURVATION finds for example that Little France Park, a corridor between existing green spaces "which is in an advanced planning stage and part of Edinburgh's green belt, faces severe pressure from real estate developers" (Kiss et al., 2019:24).

At the same time, there is also evidence that NBS are being designed and implemented in a progressive way in order to address challenges of urban inequality. In their in-depth study of the urban greening strategies of forty cities in Europe and North America, the GREENLULUs project found that half of the cities "employed greening as a way to improve living conditions and address disinvestment in socially vulnerable neighbourhoods" (Connolly et al., 2018: 23).

For example, "in the racially and culturally diverse neighbourhoods of the Nørrebro district in Copenhagen, a multi-zone new park and cycle route was developed using objects, public furniture, art and landscaping imported or replicated to represent the several dozen cultures with which residents identify" (Connolly et al., 2018: 23). Where such interventions are successful over time they appear to involve either forms of commoning - of making land or particular sites something which is either formally or informally understood to be held in common between diverse groups and stakeholders – or forms of stewardship (Morrow, 2019; Pauliet et al., 2019).

In the SHARECITY project, which focuses on urban food sharing projects including community gardens, they find that digitally enabled platforms (e.g. apps or websites that identify trees where fruit is available to harvest) as well as simple devices (e.g. shared tools) can be a means through which to generate new forms of urban commons that create ownership and engagement in urban green space (Morrow, 2019).

A key lesson from the NATURVATION project is that such forms of commoning or stewardship do not take place in a vacuum, but rely on processes of reflexive governance and purposeful mediation to be instilled and thrive. For example, Roerplein, a pocket park in Utrecht, the Netherlands, was developed with funding from the municipality and community involvement as a prerequisite. It has been "designed and implemented through back-and-forth exchanges between citizens and the municipality" with a social entrepreneur acting as a mediator, in turn triggering "the emergence of a self-organized team of local citizens supervising and maintaining the plot, which … helped other goals to surface, such as improving social cohesion and safety" (Kiss et al., 2019: 39). As the GREENSURGE project found, to be able to both generate and benefit from such forms of active citizenship, local governments need to adapt to the changing governance dynamics: next to setting the right policy frameworks and developing strategies to identify and integrate local green space initiatives, they also need to start offering flexible and context specific support to citizen-led initiatives (Ambrose-Oji et al., 2017).

8.9. CHALLENGES & OPPORTUNITIES: KNOWLEDGE, GOVERNANCE & ACTION

A wide range of projects funded under the programmes of DG-RTD over the past decade have sought to understand and implement NBS to support the development of sustainable communities. The accumulated evidence base shows that NBS can contribute to this ambition in three key ways.

First, NBS can increase knowledge about and action for nature. This has been recognised as particularly important in urban communities where opportunities for such connections may be more limited and where, as the IPBES Global Assessment reminds us, fostering values for nature will be critical if we are to address one of the key underlying drivers of the global loss of biodiversity. Increasing knowledge and action for nature is therefore not only a means through which sustainable communities can be generated in particular places, but may have wider impacts in terms of contributing to reducing our collective environmental impact globally. NBS offer a key opportunity through which this can be realised, although the extent that this is the case in rural areas has yet to be systematically investigated.

Furthermore, to date most initiatives that have sought to foster greater public participation and inclusion in NBS have been driven by municipal authorities, whereas other potential significant actors – local museums, cultural institutions, botanic gardens, educational bodies and so on – have not had a high profile within such initiatives. Engaging with these kinds of organisations as new 'agents of change' who have not to date been involved with the design and implementation of NBS may offer a further opportunity of ensuring that their importance as a space for education and value change is fully realised.

Second, research has demonstrated that NBS provide a means through which to generate new forms of collaboration and social cohesion. In both rural and urban areas, partnerships between stakeholders, forms of co-design and co-production are increasingly being used as a means through which to pursue NBS, and through these processes and practices in turn contributing fostering sustainable communities. We can identify two main approaches that have been established: first, transdisciplinary communities of practice in which one or more research organisation is involved alongside municipal and other urban actors; and grassroots community mobilisation where activists and groups have rejuvenated or established NBS as a means both of fostering social cohesion and addressing community needs. The evidence base to date suggests that both of these approaches offer significant added value in comparison to traditional mechanisms for planning and implementing urban greening strategies and measures at the local level, such as improving understanding, shared sense of purpose, commitment and long-term buy-in to the process of NBS, as well as generating a stake in their outcomes.

While such approaches are of course associated with other forms of urban sustainability, their particular advantage in relation to NBS comes from the multiple benefits that such interventions generate which cut across existing distinctions between public and private actors in novel ways. Creating a multi-stakeholder forum allows for the relations between different beneficiaries (and the trade-offs involved) to be fully recognised and new kinds of governance arrangement, business model and modes of financing to be developed and implemented. At the same time, such approaches are not without significant limitations. For the most part, rigorous processes of co-design and co-development are confined to projects that are at least in part funded under research programmes as a result of the dedicated resources in terms of time, skill and finance that are available. There is limited evidence that such initiatives have arisen spontaneously. Equally, grassroots projects are often dependent on finance and mediation skills from other actors. This suggests that, as many projects have found, there needs to be flexibility in how such approaches are designed and deployed, and that achieving some of the benefits of such approaches without striving for their 'textbook' implementation may be an appropriate way forward. Equally, there is very little evidence that these approaches have to date been attempted at scale, and indeed research from across the projects suggests that there may be scale-limitations to their implementation.

A third means through which NBS contribute to sustainable communities is through their direct impact on enhancing well-being and quality of life. There is now extensive evidence that NBS can contribute diverse values and benefits to communities, from the provision of space for recreation and social interaction to direct impacts on physical and mental health, the research and action undertaken by these projects shows the wide range of 'nature's contributions to people' that can be generated by NBS. Yet, to date most attention has focused on a few such values and benefits with in particular those related to the more spiritual or cultural aspects of nature tending to be neglected. This might reflect a relative bias in the research on NBS and their social and cultural values and benefits that has been undertaken so far, which has tended to focus on urban interventions rather than those in rural areas or which take place at the landscape scale and encompass both rural and urban areas. There is then an opportunity to more fully embrace the range of values and benefits that urban nature might provide, as well as to understand how NBS in rural spaces and at the landscape level might be reconfiguring the contributions that nature provides for people and how different people and communities are connecting to nature.

By opening up new possibilities for knowledge and values, generating social capital and cohesion, and creating values and benefits that have a direct impact on the sustainability of communities, NBS certainly offer the potential for contributing to a transformative agenda for sustainability. Yet as has been recognised throughout the projects reviewed in this section, such outcomes are far from guaranteed and there is now clear evidence that the contributions of NBS to sustainable communities are uneven and often inequitable.

In terms of participation in NBS the evidence suggests that challenges of moving beyond the inclusion of a relatively narrow section of society and/or a group of alternative but familiar voices remains strong. While most projects point to ways in which processes of inclusion can be made more effective and more open, there are fewer examples where deep reflections on how such projects and the ideas of nature they contain may serve to exclude. In short, there has been a good deal of willingness to change how processes for NBS are organised and deployed, but fewer that have really sought to radically open up the question of what kinds of nature should be generated and for whom the solutions should be designed. This in part reflects the challenge of thinking through what the purpose of urban greening is and who stands to benefit.

There is now significant evidence that the outcomes of urban NBS can serve to generate new forms of inequality and exclusion. Much of the critique of green gentrification is directed at projects that are explicitly seeking to generate increased economic value from the inclusion of urban nature at the expense of the views and concerns of existing communities. Where such forms of exclusive green development are taking place, there may be a role for public authorities or civil society to require or request that additional public goods (e.g. in the form of storm water drainage or urban cooling services) are generated to compensate for a lack of direct access to urban green space. Yet also of concern are more subtle and often inadvertent forms of exclusion that arise through a lack of consideration of the ways in which NBS may serve to entrench or create inequities. It is also striking that there is little to no evidence about how the development and implementation of NBS in rural areas or at the landscape level may also be creating new kinds of inequality.

At the heart of this challenge is not only the question of getting processes and outcomes of NBS to generate social inclusion and fairer access to the values and benefits that are created, but a deeper question about whether such interventions have so far been able to address the underlying drivers of social inequality and the roots of un-sustainability. Concerns are raised, for example, that NBS may be used to justify more urban development and growth, creating demands for raw materials, land and energy that are incompatible with demands for global sustainability. To foster sustainable communities, it will be necessary to also draw on the evidence of how new and radical forms of urban (re)development can take place in various temporary and partial forms through the use of NBS and to avoid a 'one size fits all' model of urban futures.

8.10. POLICY RECOMMENDATIONS & KNOWLEDGE GAPS (SUSTAINABLE COMMUNITIES)

NBS provide a key means through which wider goals for sustainable communities can be achieved, but it is clear from this evidence review that there is no panacea to be found in bringing fostering new processes for participation and inclusion or through the use and development of specific kinds of community-based process, such as living laboratories, participatory planning, transition arenas and so forth. While each of these kinds of interventions can make a difference in specific places and to particular people, there is strong evidence that if they are to fully contribute to realising sustainable communities, NBS will need to be designed and implemented with the explicit intention of addressing underlying inequalities and tensions of urban and rural development. From these broad findings, a number of policy recommendations can be identified:

- Use co-design and co-production processes in moderation and be aware of their limitations. These approaches are useful for enhancing goals for sustainable communities, but are unlikely to be able to be applied at scale or to overcome existing forms of inequalities.

- Explore the potential for engaging new agents of change within the design and implementation of NBS, including for example faith groups and places of worship, insurance companies, business associations and the health sector.

- Ensure that new NBS do not contribute to green gentrification through ensuring that those who are likely to be most affected by changing land and rental values are included in the design of new projects and are afforded some form of stake in the outcomes that result.

- Create tools to capture and map the benefits and beneficiaries of NBS, and identify sectors (e.g. health, risk reduction, economic development) where the connections between the value of NBS and policy goals have not yet been established in order to develop new communities of knowledge and practice within government for NBS.

- Develop new financial instruments and business models that can socialise the costs of NBS in conjunction with governance approaches that enable their benefits to be shared by those who gain from proximity to such interventions and those who may inhabit other parts of an urban or rural area, in turn increasing access and addressing urban inequalities.

While an extensive evidence base about the potential of NBS is being developed, key knowledge gaps also remain where further research could support enhanced implementation and outcomes:

- Much of the research on the role of NBS for sustainable communities has been conducted in an urban environment, with the result that we have more limited understanding of how such interventions might support the development of rural sustainability or the generation of sustainable communities at the landscape level across both urban and rural domains.

- There is some evidence that proximity to and experience of nature is an important issue in shaping the values that individuals hold about wider sustainability challenges and the actions they should take to address these issues (e.g. through changes to daily practices or forms of consumption). Further research is needed to explore the role of NBS in generating new kinds of connections and values for nature and with what consequences.

- There has to date been limited research on the ways in which diverse forms of urban/rural nature are valued and through which means, and this has had little impact on the design and implementation of NBS which tend to prioritise established expertise over local knowledge and values and to miss the opportunity of taking diversity in terms of what is seen to be valued in the natural environment into account in their design. Further research could explore what counts as nature, what is valued and why this varies amongst individuals and communities as well as how this can be taken into account in the development of future NBS.

- Further research is needed into how business models, finance mechanisms and governance arrangements can be established that enable the implementation of NBS without generating large increases in the value of land and property that in turn produce forms of green gentrification.

- It appears that forms of stewardship, commoning and other kinds of shared ownership or visible stake in NBS are important for the long term engagement of communities and for sustaining NBS over time. Further research is needed to examine how such approaches can be established within current systems of governance and what new kinds of powers, capacities and financing might be required to enable local authorities or other actors to generate such initiatives.

Governing NBS
Towards transformative action

Harriet Bulkeley

9. GOVERNING NBS: TOWARDS TRANSFORMATIVE ACTION

9.1. INTRODUCTION

How, by whom and at what ends NBS should be governed has come to occupy a central place within debates about their potential to address sustainability challenges. Frequently, the governance challenge for NBS is regarded as largely a matter of implementation and the questions becomes one focused on which governance conditions, arrangements or mechanisms are needed to ensure that NBS can be effectively implemented (at scale). Indeed understanding the barriers and possible solutions to implementing NBS such that they can become mainstreamed within urban development has been a core goal of the H2020 Sustainable Cities and Communities programme.

At the same time, there is growing interest in the extent to which the governing of NBS can be transformative of the ways in which sustainability challenges are addressed and in terms of the outcomes for nature and for society. This imperative has been driven by recent calls from both the Intergovernmental Panel on Climate Change (IPCC) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) for transformative change to meet both climate and biodiversity goals, which are in turn shaping policy agendas in each of these domains. For the IPCC, the concept of transformation relates to "the need for urgent and far-reaching changes in practices, institutions and social relations in society. Transformations towards a 1.5°C warmer world would need to address considerations for equity and well-being" (Bazaz et al., 2018: 468).

Importantly, the IPCC notes that the "form and process of transformation are varied and multifaceted" whilst also maintaining that pathways are needed for future action that "enhance the prospects for effective climate action, as well as enhanced poverty reduction and greater equity." In a similar vein, the IPBES Global Assessment (Diaz, 2019: 5) defines transformative change as "a fundamental, system-wide reorganization across technological, economic and social factors, including paradigms, goals and values" though questions of equity and justice are not explicitly placed at the heart of this agenda.

This section focuses therefore on the governance challenge for NBS as both one of implementation and one of transformation. Whilst there is extensive discussion in the academic literature about what constitutes governance and how it is best defined, at the heart of the concept is the issue of how and by whom governing takes place.

Governing in its broadest sense involves guiding or directing the actions of others and is a specific form of power that carries authority (Ruggie, 2004). In short, to govern is to exercise authorised power – that is, power that is recognised as legitimate (Allen, 2004; Bulkeley, 2015).

Over the past three decades there has been a growing interest in the multiple modes through which governing is conducted as both the authority and the capacity of traditional forms of state-based governing appear to be giving way to a more fragmented landscape in which various actors are engaged in diverse forms of governing through partnerships, networks and interventions taking place across multiple levels of societal organisation and an increasing array of sites, from specific place-based initiatives to those emerging in supermarkets, across value-chains and through social media. With their focus on generating multiple benefits for a range of societal actors and largely taking place through dispersed initiatives, NBS may both profit from and further exacerbate this trend toward a more fragmented governance landscape. At the same time, concerns are expressed that the diffusion of the capacities and levers to govern means that it is difficult for NBS – as with other such initiatives – to gain the traction and co-ordination needed to become fully integrated and embedded within mainstream policies and practices for land management, water regulation, urban development and so forth needed in order to ensure that they are deployed at scale.

Evidence from the projects concerning how NBS are governed tends to take two forms. First, and most common, are approaches which adopt either a deductive approach or normative perspective and proceed by using conceptual models to guide the design (and implementation) of governance arrangements or approaches through which NBS can be developed to achieve particular outcomes. Such approaches have used a range of different underpinning conceptual models, including those that are derived from theories of socio-technical transitions, adaptive governance, and participatory planning, and identify key mechanisms or principles that can be used to underpin the design of NBS projects. In this sense, they are concerned with generating 'ideal type' institutions and processes through which governing can take place.

In this set of approaches, the intention is to either test the validity of such approaches or generate learning about how they can be enhanced (where a deductive approach is being followed), but in other cases the design and implementation of governance for NBS is guided by principles about what constitutes 'good' governance (for example greater inclusion or transparency in decision-making). This evidence base can inform our understanding of which kinds of principles are seen to be essential for governing NBS, and where learning and evaluation processes have been put in place can also enable reflection on the validity of some of the underlying assumptions about how the governing of NBS works in different conceptual models.

A second set of approaches used across the projects in order to understand the governing of NBS involve the use of either an inductive approach or a critical perspective. These approaches are primarily used to understand how governing is working in practice and with what (unintended) consequences, with the intention of using this evidence gathering to build a picture of the challenges and opportunities for governing NBS. Such approaches are particularly useful for building new concepts, ideas and theories, and can also be used to interrogate how and why different forms of governing NBS are more or less successful. Often research of this kind stops short of being prescriptive in terms of making recommendations about the design and implementation of future NBS, which may be why it is less often used as the basis for understanding the potential and limitations of different approaches for governing NBS.

In practice, many projects adopt a mixture of these two main approaches in developing their assessment of the ways in which NBS can and should be governed. It is however important to recognise the distinction between findings and recommendations that are derived from deductive and normative approaches – which often provide clear prescriptions for future action but where the evidence base may be primarily based on conceptual models, normative commitments and a relatively small number of case studies – and those which are derived from inductive or critical perspectives – which often lack precision in terms of identifying actions to be taken but where the underlying evidence may be more robust.

A particular challenge facing any analysis of the governance of NBS is the relatively limited evidence base in the academic literature that focuses on either NBS or related initiatives, such as green infrastructure (Sekulova & Anguelovski, 2017; Egusquiza et al., 2017). As a result, many of the projects in the EU portfolio have tended to adopt a more deductive/normative approach, which in turn tend to draw from conceptual models and ideal types generated for sustainability challenges in general rather than that are related to NBS specifically. Nevertheless, as these projects progress a number of valuable insights are being generated.

The remainder of this section examines what the evidence base accumulated to date suggests about the modes of governing that are being deployed to support NBS, before turning to consider the particular factors that shape how NBS can be governed and specific examples of how these can be addressed in practice. The potential for enabling transformative approaches to governing NBS are then considered, before identifying key policy recommendations and knowledge gaps.

9.2. MODES OF GOVERNING NBS

9.2.1. Categorising modes of governing for NBS

A central consideration in the shifting landscape of governance over the past three decades since sustainability came to be a key policy priority has been the recognition that governing is both multi-level and multi-actor. Predominantly used to describe the position of urban or local authorities within the broader governance landscape, multilevel governance refers to the institutional arrangements and networks that operate both 'vertically' and 'horizontally' and shape the responsibilities and capacities for governing experienced by different actors (Fuhr et al., 2018).

TABLE 25. NATURE4CITIES five clusters of governance (Egusquiza et al., 2017)

CLUSTER	GOVERNANCE APPROACHES
Traditional public administration	Hierarchical governance
	Closed governance
	Participatory planning & budgeting
New public management	Public-private partnership
	Business-led self-governance
Private-private partnerships	Non-state market-driven governance
	Business-NGO partnerships
	Sustainable local enterprise networks
Societal resilience co-management	Civic ecology practices
	Self-governance/grassroots initiatives
Network governance	Collaborative governance
	Adaptive governance
	Adaptive co-governance
	Adaptive co-management
	Scale-crossing brokers

Across this multilevel governance landscape, analysis has shown that there are forms of governance that are more akin to traditional, state-based hierarchical governing, those which are market-based forms of governing, and those which are driven by civil society. Identification of the different forms or modes of governing through which sustainability in general and NBS in particular take place is often described according to one or both of these frameworks, which enables the identification of both the structure and the agency being deployed.

Through their survey of the relevant literature, NATURE4CITIES suggest that five different clusters of governance approaches can be identified that have relevance for NBS (Table 25, Egusquiza et al., 2017: 60-61). Such an approach provides a helpful summary of a vast range of possible starting points through which to consider the means by which governance for NBS takes place and the kinds of actors involved. Each cluster represents different orientations to the idea of governance – from more normative terms or specific concepts that have been used to identify particular attributes of governing and their consequences to more diagnostic terms – and within each there are a mixture of specific governance instruments (e.g. participatory planning) and forms or governing (e.g. hierarchical governance). Nonetheless this survey of the literature points to the vast number of ways in which the governing of NBS could be taking place and also to the shifting landscape of governance itself.

Rather than focusing only on the actors, arrangements and instruments of governing, other approaches give more detailed consideration to how governing is undertaken by considering the ways in which power is exercised. In their initial work on the modes of governing deployed for urban climate action, Bulkeley & Kern (2006) found that municipal authorities used different forms of power/authority to govern and that the capacity to govern was not only confined to formal powers but also took place through less explicit kinds of power, such as those related to enabling or persuasion and through more direct means such as providing services.

Building on this approach and subsequent iterations that have been developed in the literature over the past decade and more, NATURVATION's analysis of fifty-six NBS initiatives in eighteen cities globally suggests that twelve modes of governing can be identified (Table 26; see also Bulkeley, 2019). In each mode, different actors and means of governing are involved, in turn suggesting that governing NBS can emerge in a variety of different ways. This is particularly important because a challenge of a lack of capacity or regulatory authority to govern NBS is often presented as a barrier to action. By shifting focus to the multiple modes through which governing can take place, it is possible to think about ways in which diverse forms of governing capacity can be harnessed through multiple different agents of change.

9.2.2. Modes of governing in practice

Analysis of over 970 NBS initiatives in a hundred cities in Europe by the NATURVATION project reveals that 30% of all NBS surveyed are led by public actors, 26% by non-governmental actors, and 44% jointly by public and non-governmental actors (Almassy et al., 2017). Within this last category, private sector, non-governmental organisations and community groups were the most frequent non-state actors involved. Analysis of this dataset also suggests that the trend towards co-governance approaches, which take multiple forms, has increased over time with a higher proportion of those NBS that were established more than 10 years ago being led by public actors compared to today where forms of co-governance dominate (Almassy et al., 2017).

This evidence suggests that there are wide variety of forms of governance experimentation emerging in relation to NBS, within which municipal governments are playing various roles but where there are also strong roles for private actors, non-governmental organisations and community groups.

This picture is no doubt partially a reflection of broader trends within the governing of urban sustainability, where issue areas are increasingly linked to one another through recognition of the co-benefits that different types of intervention are able to generate, where the authority to govern is dispersed and the capacity to enable and implement change is unevenly distributed and shaped by prevailing economic conditions (Bulkeley, 2019). At the same time it is likely to reflect some of the key challenges that have been identified in terms of governing NBS. The CLEVER CITIES project for example identifies these as relating to the challenge of capturing multiple benefits that NBS provide and of ensuring that diverse beneficiaries are involved in the design, implementation, and ongoing maintenance of such interventions, a lack of political and financial support and insufficient inclusion of social groups (Schmalzbauer, 2018).

TABLE 26. NATURVATION 12 MODES OF GOVERNING FOR NBS

GOVERNING APPROACH	DEFINITION
In-house (municipality)	NBS is designed, implemented and financed within the municipal organisation.
Public provision	NBS is provided by a public authority or public agency: it is designed, implemented and financed by (one or more) public authorities/agencies.
Public-private provision	NBS is provided by group of public & private authorities, agencies and organisations that are linked through a formal institution or legal agreement (e.g. they form a consortium, a partnership with legal standing). The NBS is designed, implemented and financed through this consortium (i.e. there are no other organisations who work in partnership with this entity but remain external to it in formal/legal terms).
Regulation	The design and implementation of NBS is undertaken by a private sector organisation/civil society group in response to a regulatory requirement provided by a public authority or agency (at any level of governance). Financing could be provided by the initiating actors or another source (public/private/civil society).

GOVERNING APPROACH	DEFINITION
Incentives	The design and implementation of NBS is undertaken by a private sector organisation/civil society group in response to an incentive provided by a public authority or agency (at any level of governance). Financing could be provided by the initiating actors or another source (public/private/civil society).
Enabling & supporting	The design and implementation of the NBS is undertaken by a private sector organisation or civil society group in response to enabling and supporting measures – such as support with developing knowledge about NBS/their potential, signposting to relevant sources of financial or other support, the provision of access to resources or land, donation of some resources - provided by a public authority or agency (at any level of governance). The financing of NBS could either be provided by the initiating actors or come from another source (public/private/civil society).
Partnership – public sector led	The design, implementation and financing of NBS is undertaken in partnership, where different authorities, agencies, organisations and groups contribute towards a joint undertaking but without becoming constituted as one entity in legal or institutional terms. Partnership initiated and led by a public sector authority, agency or group (at different levels of government).
Partnership – civil society led	The design, implementation and financing of NBS is undertaken in partnership, where different authorities, agencies, organisations and groups contribute towards a joint undertaking but without becoming constituted as one entity in legal or institutional terms. Partnership initiated and led by a civil society organisation/group (i.e. composed of actors from civil society and operating on a not-for-profit basis).
Partnership – private sector led	The design, implementation and financing of NBS is undertaken in partnership, where different authorities, agencies, organisations and groups contribute towards a joint undertaking but without becoming constituted as one entity in legal or institutional terms. Partnership was initiated and led by a private sector organisation or group.

GOVERNING APPROACH	DEFINITION
Private-sector led	The design and implementation of the NBS is undertaken by private sector organisations or civil society groups, where the initiation of the NBS is driven by a private sector organisation and it provides the enabling conditions/support required for its implementation. The financing of NBS could either be provided by the initiating actors or come from another source (public/private/civil society).
Philanthropic/Not-for-profit	The design and implementation of the NBS is undertaken by private sector organisations or civil society groups, where the initiation of the NBS is driven by a philanthropic or not-for-profit organisation and it provides the enabling conditions/support required for its implementation. Financing could either be provided by initiating actors or from another source (public/private/civil society).
Community driven	The design and implementation of the NBS is undertaken by civil society groups, where the initiation of the NBS is driven by a community group and it provides the enabling conditions/support required for its implementation. Financing could either be provided by the initiating actors or another source (public/private/civil society).

Despite the wide array of different modes of governing being used in the implementation of NBS, the evidence base built through the portfolio of projects developed under the FP7 and H2020 programmes to date has been built on two primary types – municipality-led and co-creation – reflecting the requirements of the funding that has been provided.

Turning first to those projects which have investigated or developed municipally-led NBS including those that are based on municipal plans for urban greening and NBS and those which include the direct provision of NBS by local authorities, much of the evidence base has focused on different ways in which communities and stakeholders have been involved in the design and implementation of plans and projects and with what consequences. As the NATURE4CITIES project suggests, a key issue is that of how implementation models can be generated that are perceived as fair by stakeholders, that secure their engagement and NBS also produce desired outcomes (Egusquiza et al., 2018).

The UNALAB project documents the importance of strategic planning frameworks at a local and national level in generating such conditions. In Eindhoven, the Netherlands, researchers found that the Green Space Policy Plan provides an "overarching green strategy and guiding principles for green developments in the city, whilst at the same time being used to inspire and inform local stakeholders and citizens", with several different local initiatives being involved in the review and update of the strategy to bring stakeholder and community perspectives to the table (Hawxswell et al., 2018). In Stavanger, UNALAB found that the embedding of public participation in national law provided a strong driver for ensuring citizen engagement in planning processes which was also sustained by a growing interest amongst citizens in shaping urban development plans (Hawxswell et al., 2018). The GREEN SURGE project found multiple examples of citizen and stakeholder participation of this nature, and a growing interest amongst municipalities in harnessing 'active citizenship' through which citizens make an positive contribution to both societal goals and their own lives (Ambrose-Oji et al., 2018).

BOX 58. CO-PRODUCING IN TAMPERE, FINLAND

In Tampere, Finland, the Municipality established a site for urban experimentation on the derelict grounds of a former paper factory. The resulting district, Hiedanranta – Smart and Sustainable City District of the Future, was initially designed through an international competition for development companies to present different visions for the future. from the ideas submitted, two were selected by a jury and a process of co-creation with citizens, local companies, the local research institutions and municipal employees undertaken to develop the detailed design and planning for the district. The planning department supported the development of this master-planning process and dedicated funds were provided to support all stages of the development and implementation of the design process. The new district was exempted from some legal obligations, such as building codes, in order to promote experimentation and innovation. This has led to initiatives such as rooftop urban farming systems and decentralised sanitation provision. The combination of experimental approaches to both the design and development of the site, alongside a dedicated project team and funding, has allowed for "radically new technologies, management schemes and joint creation methods to be implemented" and provided a set of examples from which the municipality and other cities can learn.

Source: Hawxswell et al., 2018: 80-81

Alongside a focus on municipality-led NBS that deploy more or less extensive forms of citizen and stakeholder consultation and engagement, a second core mode of governing that has been at the centre of the projects reviewed here focuses on co-creation or co-development. In such approaches, municipal authorities together with research organisations and frequently also with community groups and some private sector actors establish either real-world experiments or forms of living laboratory in which new NBS initiatives can be generated. There is a strong focus on the co-production of knowledge about the particular challenges or issues that are to be addressed and viable solutions, as well as the subsequent design and ongoing learning from specific interventions.

As the ARTS project sets out, central to such initiatives are specific dedicated spaces for interaction and experimentation, and while local governments are seen to provide important "formal spaces of interaction with consultations and other forms of interaction" so-called 'transition initiatives' which are deliberately designed to foster learning and transitions for sustainability themselves "create self-organised spaces for interaction, meeting and debate even more frequently in cities, such as festivals and thematic gatherings" (Gorissen et al., 2018).

Whether through more traditional policy approaches or in novel collaborations, participation of stakeholders and communities is seen to be a means through which governance can be strengthened and made more effective in three main ways – through enabling inclusion, building capacity and by fostering the scaling up of initiatives. As the OPENNESS project suggests (Turkelboom et al., 2017), such approaches can foster participation enabling the inclusion of diverse views and needs, increasing transparency and helping to deal with trade-offs and conflicts, with the expectation that when "conducted properly, the resulting plans will lead to more co-ownership, higher public support [and] a higher likelihood of implementation."

At the same time, as discussed in the previous section on sustainable communities, there are concerns that the ways in which such processes not only fail to address existing inequalities but may serve to embed them further. Elaborating on the possibilities and limitations for harnessing active citizenship GREEN SURGE suggest that such strategies could "impede inclusiveness" because they depend on forms of cultural capital that are unevenly distributed. As a result, if accompanied by a retreat of the state "an increased reliance on nongovernment led initiatives could lead to unintended impacts on environmental justice and the fair distribution of access to public green space" (Ambrose-Oji et al., 2017). Where participatory approaches for governing NBS are put in place it is of critical importance to ensure that such potential outcomes are mitigated against through ensuring that measures are put in place to enable those who are usually excluded from decision-making processes are able to participate and that diverse views are recognised.

When it comes to building capacity, URBAN GREENUP find that collaborative planning can increase institutional capacity "by bolstering formal institutions, filling institutional gaps, producing action agendas, and generating innovative ways of solving problems" whilst also building "social, political and intellectual capital within governance systems, which in turn provides new knowledge" (Urban GreenUp, 2019). In short, such approaches can be seen as responses to the limited capacity and knowledge held within municipal authorities when it comes to the multiple benefits of NBS, providing a means through which the diverse views, values and understanding of what NBS can contribute to diverse stakeholders and communities can be captured and used to strengthen governance and implementation. Likewise, such governance initiatives are also seen to be important in enabling the scaling up of NBS in order to support broader sustainability transitions.

Work undertaken on sustainability transitions has shown that initiatives that are designed as experimental or learning spaces can support various processes through which sustainability can become mainstreamed (Turnheim et al., 2015). At the same time, there is also evidence that it can be challenging to develop and implement 'one size fits all' approaches. As the SMR project found, while decision-support tools that were intended to be readily transferred from one context to another in reality each city involved in the project "developed its own communication processes, relationships and priorities based on the infrastructure available, messages that need to be communicated, the way in which their citizens reach out to them and the staff capacity and resources available" (Grimes et al., 2016).

BOX 59. ACCELERATING SUSTAINABILITY TRANSITIONS?

Research undertaken by the ARTS project in Genk, Belgium, found:

- Upscaling is often hampered by 'limits to growth', e.g. many initiatives are still struggling to grow beyond the already established sustainability scene (e.g. the environmentally conscious);
- Replication appears to be supporting diversification of sustainability initiatives in terms of low carbon themes and practices and allows alignment to the passions of the initiators and to local needs;
- Partnering and embedding promote diffusion to the wider public and are favourable for institutionalisation and possibly routinisation. Partnering appears to be a requisite for instrumentalisation and embedding; and
- Instrumentalisation helps to promote the survival of the transition initiative, but also appears to be conducive for upscaling, replicating and partnering.

Source: Gorissen et al., 2018

9.2.3. Enabling the governance of NBS

Developing and sustaining NBS is seen to present many governance challenges, ranging from problems encountered by a lack of knowledge about their costs and benefits or the challenges of finding consistent and measurable indicators through which to monitor progress, through to the lack of regulatory powers, planning control and legislation that can support the implementation of NBS, the inertia of 'business as usual' approaches to the provision of housing and infrastructure and the dominance of other priorities. Many of these challenges have been encountered across a wide variety of sustainability domains – from transport to energy, agriculture to coastal protection. At the same time, a number of core factors can be identified that shape the governance of NBS specifically and where new kinds of governance arrangements, strategies and mechanisms can be used to enable their implementation and long-term viability.

9.2.4. Developing a multilevel governance approach

While much of the attention to date has focused on the governance challenges encountered in the local implementation of NBS, it is important to develop a multilevel governance approach in order to enable NBS. Multilevel governance is a term used to describe formal and informal institutional arrangements within which local actors are embedded and which shape their governance capacities, involving both 'vertical' relations between tiers of government and 'horizontal' relations across government departments, between local authorities and amongst state and non-state actors (Bulkeley & Betsill, 2013; Fuhr et al., 2018).

NBS, like many other sustainability challenges, are governed through a multilevel governance landscape, with the capacities and autonomy of local actors shaped by national and European policy as well as through networked relations of expertise and resource mobilisation. A particular feature of NBS is that given their multi-faceted character and the diverse forms of benefit that they generate – from health to climate change, biodiversity to economic regeneration – they inhabit a highly complex multilevel governance field, crossing over different policy domains and requiring multiple agendas to be aligned in order that they can harness sufficient capacity and resources to be sustained over time.

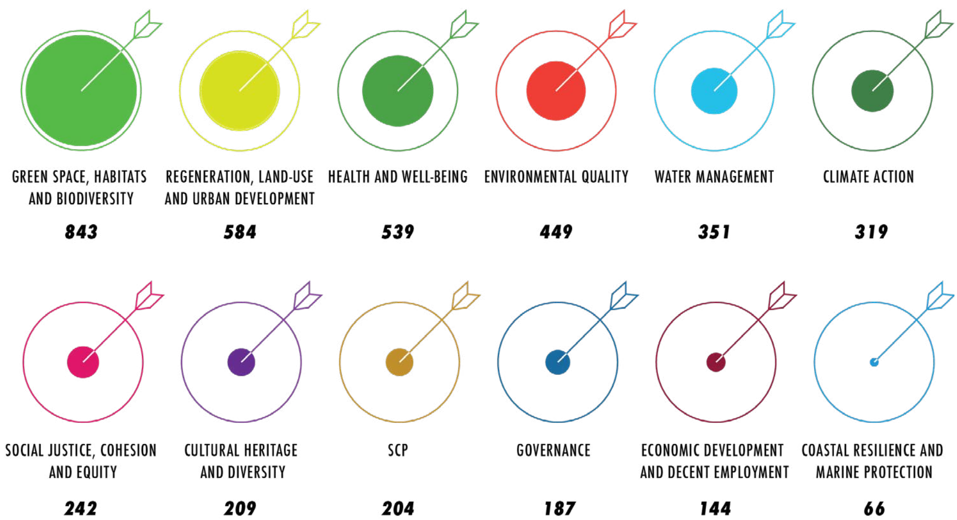


Figure 38. Frequency of sustainability challenges addressed by NBS in the Urban Nature Atlas

Research undertaken by the NATURVATION project found that while NBS being undertaken in cities tend to prioritise green space, well-being and health, and economic regeneration, within the policy arenas operating at national and European levels NBS are being driven by climate, biodiversity and water agendas (Almassy et al., 2017; Figure 38). This misalignment presents important 'opportunity gaps' for aligning policy agendas. Existing NBS that are being driven by concerns for access to green space, health and well-being may also be generating benefits for climate and biodiversity without this being explicitly recognised. Equally, health and economic regeneration policy agendas at national and European levels may be missing the important value placed on NBS and the impacts that they can have.

NATURVATION identifies four key tools that can be used to enable more effective multilevel governance for NBS by breaking down silos, building networks across policy domains and establishing the multiple beneficiaries that NBS can support (Bulkeley, 2019, Figure 39).

Regulatory tools, voluntary standards and certification schemes can also support the development of an enabling multilevel governance landscape for NBS by establishing expectations for the use of NBS and standardising responses. In the UK, the proposed introduction of mandatory biodiversity net gain for urban developments is leading the development industry to explore the use of NBS in both urban and rural areas as a means through which they can meet their regulatory obligations (van der Jagt et al., 2019)

Filling the Gap: use four key governance tools that work

Figure 39. Governance tools for aligning NBS within multilevel governance systems

NBS generate both public and private benefits (as well as costs). While other sustainability interventions can be considered to perform similarly – for example, the installation of solar panels or the use of electric vehicles produces public benefits in terms of reducing greenhouse gas emissions and local air pollutants as well as cost savings or improved service for the individuals concerned – the private benefits of NBS are more difficult to enclose and translate into monetised returns (see section 10). For example, the benefits of providing NBS in an urban development for residents to improve health and well-being also generate other local benefits for nearby communities, potentially provide means through which to manage excess water in urban areas and contribute to the management of flooding or generate new habitats which contribute to supporting biodiversity. While some 'private' benefit for the urban developer may be returned through higher property values (e.g. see Wild et al., 2017), the other benefits of NBS are enjoyed by diverse beneficiaries, across multiple spatial and temporal scales and often with no way of their value being returned to those who initiated the implementation of NBS in the first place.

The public/private and inherently uncertain character of NBS means that particular forms of governance may be especially beneficial for supporting their uptake. As noted above, public-private partnerships, co-design approaches, and those which involve civil society working together with businesses and governments are becoming prevalent, demonstrating their value to those actors working with NBS. Such arrangements often have to overcome rules and procedures, especially within local government, that hinder effective co-operation. The development of intermediary organisations – which operate as a meeting place or broker between different actors - can be a helpful means of enabling more effective co-operation of this kind. Equally, new forms of platform such as crowdfunding or living laboratories, as well as area based partnerships or landscape initiatives which bring together diverse actors can also support the development of NBS. Within such arenas and partnerships, NBS are often valued because they are flexible – the very characteristics that makes them difficult to rely upon can also be an advantage, as NBS can be incrementally implemented (reducing upfront costs of investment), adjusted in the light of experience and changing conditions, and undertaken on a temporary basis. While such temporary fixes may not lead to any permanent change on the ground, they can alter perceptions on the value of NBS, create new communities of practice, shift expectations amongst the public and may lead to other temporary interventions elsewhere – creating a mosaic landscape of NBS across the city which shift over time (Ambrose-Oji et al., 2017; Buijs et al., 2019).

BOX 60. ENABLING TEMPORARY NBS IN BERLIN, GERMANY

As part of the city's Urban Landscape Strategy, Berlin developed the Urban Pioneers project at the former airfield, Tempelhofer, which is now one of the city's largest parks. Involving around twenty temporary uses of space, from culture and art to learning, sport and gardening, each initiative was developed and supported by members of the local community. The aim was that these kinds of temporary use of the park could contribute towards sustainability goals, improve its appearance and kick-start innovation and development. Some temporary uses have become more permanent. One example is the Allemende-Kontor community garden, which started from just 10 raised beds and has grown to 250 over a few years that are now used by over 500 people whilst also developing connections to other community gardens in Germany.

Source: Hansen et al., 2017: 80

9.2.6. The challenge of evaluation

Acknowledging that the benefits of NBS vary in time and space and come in many shapes and sizes makes the task of evaluation a challenging one. Evaluation frameworks tend to include few common indicators, and a significant advance has been made by the creation of a Task Force dedicated to developing a common indicator handbook for use in planning and evaluation in cities across Europe. Alongside developing the sophistication and ease with which benefits of NBS can be identified and monitored, there is also a significant challenge of ensuring that the full range of potential beneficiaries are engaged with NBS – for example, to date actors from the health and insurance sectors have tended to be relatively less involved than from other areas of government and business.

An additional complicating factor is that the benefits of NBS cannot be known and predicated in the same manner as those for 'fixed' interventions such as flood protection walls or concrete drainage systems. NBS are often context dependent, and the benefits they generate will depend on their local situation as well as weather, soil and wider environmental conditions and how these change over time. Evaluation techniques, models and governance arrangements (e.g. performance contracting) that focus on the delivery of constant levels of service over the long-term are therefore likely to undervalue NBS, both because of the qualities of infrastructure that are being valued and because of a lack of detailed, in-situ knowledge about the performance of diverse NBS. Detailed monitoring and evaluation can be expensive (and it often not undertaken outside the context of specific research and implementation projects) and there is often a lack of capacity and expertise at a local level to work with the information available.

9.2.7. Enabling dissent and contestation

An overarching feature of discussion about the potential for improving the governing of NBS is that it focuses on the value of consensus – the more actors are able to share the same views on NBS, the more readily they can be implemented and the challenges of sustainability addressed. Ensuring that NBS are implemented in a legitimate and democratic manner is of course paramount. Yet the evidence base also shows that in well-meaning efforts to develop consensus for NBS, concerns and alternative perspectives can be dismissed.

As section 8 explores in detail, there is significant evidence that NBS can be limited in terms of their capacity to foster inclusion and meaningful participation in decision-making and implementation. Yet even if such processes were perfectly designed and implemented, it is important to recognise that NBS will generate dissent and contestation and to establish governance arrangements and processes accordingly to benefit from rather than control such dynamics.

NBS generate dissent and contestation much like any other intervention designed to improve social and environmental conditions because our understanding of the problem to be addressed is not uniform or universally shared. This is exacerbated by the multifaceted character of NBS – because they are often implemented with the notion that they can generate multiple benefits and hence address many different challenges, there is greater scope for each of these problems to be understood in different ways, such that the potential for different and incompatible views about NBS are magnified. For example, urban developers may regard NBS as a means through which to enhance land values and generate additional benefits to future residents, whereas local communities may regard such interventions as privatising previously accessible open space.

NBS also have the added quality of being positioned as necessarily beneficial because they are ‘nature-based’ – more nature is usually regarded as a good thing almost without qualification. Yet different groups within society hold diverse values for nature, such that any interventions in an urban neighbourhood – whether this is a manicured lawn or a wildlife haven – will not be universally welcomed. There is here though a risk that the potential negative sides of NBS are then hidden from view. There is now a very active debate about the possibilities that adopting ‘natural solutions’ for climate change may both provide an excuse for inaction in terms of the reduction of greenhouse gas emissions and may lead to detrimental impacts on biodiversity (section 4).

New governance tools and approaches for ensuring the development of NBS where negative side effects are minimised is one approach through which to address this challenge. The IUCN, for example, is developing a standard for NBS that seeks to encourage those implementing these kinds of initiatives to ensure that quality thresholds for a number of criteria - from participation to impacts on biodiversity - are met. To date, this approach is primarily aimed at large scale NBS designed to be implemented in rural areas, and a similar standard or certification scheme is not in place for urban NBS. Nonetheless, advancing such standards and forms of certification could enable more effective forms of governance through public procurement and private investment. At the same time, creating processes through which dissent can be voiced and contestation take place will be vital if NBS are to be taken forward at scale. This can be particularly challenging when such initiatives are - as discussed above - necessarily implemented through new kinds of governance arrangements which do not have formalised processes for these kinds of issues to be aired and taken into account.

Developing co-governance approaches that have some capacity for democratic engagement by those outside the partnership or alliance may be an important next step. Equally significant are approaches which deliberately seek to bring those who have radically different views, disagree or wish to oppose NBS into dialogue, not only to find new forms of consensus but to consider whether parallel and diverse interventions are possible that take different perspectives on how, by whom and to what ends NBS should be implemented.

9.3. TOWARDS TRANSFORMATIVE GOVERNANCE?

While much of the evidence base gathered through the H2020 research and innovation projects has sought to understand how we can improve their implementation, there has also been a concern with understanding what might be required to develop transformative change with and through NBS. The idea that responses to sustainability challenges should be transformative has rapidly risen up the policy agenda in the past few years, particularly fuelled by concern that progress in addressing the related challenges of climate change and the loss of global biodiversity has been inadequate.

BOX 61. EMPOWERING INDIGENOUS COMMUNITIES

A case study from Winnipeg undertaken by NATURVATION illustrates how community-based plans working with urban nature to address the challenges of social inequality (especially for the indigenous population), food security, and people's health and wellbeing. In the Spence Neighbourhood located in the inner city of Winnipeg, which is one of the most disadvantaged urban area in Canada, a grassroots-run neighbourhood group – the Spence Neighbourhood Association (SNA) – is working with indigenous communities and local stakeholders to transform more than 50 vacant lots into edible community gardens, tot lots, and parks. Besides the conservation values, these urban green spaces provide important social, economic and environmental benefits. For example, in the Ogimaa Gichi Makwa Gitigaan garden opened in 2012, the inclusion of indigenous plants in the garden not only contributes to the conservation of local species, but also allows community members to utilize traditional knowledge while learning about horticultural practices.

Source: Hansen et al., 2017: 80

Across the projects reviewed for this report, transformational change is also in focus. For some, transformational change comes through the shifts in socio-technical and socio-ecological systems that take place via the implementation of NBS. For example, urban drainage systems can be transformed from existing 'grey' to 'green' modes of operation, housing provision can be redesigned to include green roofs and open spaces and so forth. For others, transformational change has to take place at a structural level, shifting the balance of power between different actors and creating new forms of economy. Here projects document the role of NBS in creating forms of 'mosaic governance' in which power for urban (re)development comes to lie in the hands of communities, or where new localised economies are generated around community gardens and food growing projects.

Whether system change or structural change is in focus, there has also been a significant effort to consider the extent to which processes associated with the implementation and ongoing maintenance of NBS can be considered to be transformative. Here, as discussed in section 8, work has focused on new forms of co-production and co-design, as well as on increasing participation in the design of NBS. While this has led to new actors and communities being involved in addressing sustainability, at the same time there is less evidence that such approaches have been transformative in terms of addressing the root causes of inequality or exclusion which require not only the principles of equitable rights and responsibilities for participation are enacted but that forms of justice as recognition are pursued (Bulkeley et al., 2013; Kiss et al., 2019). This also appears to be the case in terms of the outcomes of NBS, which can be seen to have improved access to the benefits that such interventions offer in relation to sustainability but so far not to have been deployed with the intention of addressing persistent social, economic and environmental inequalities.

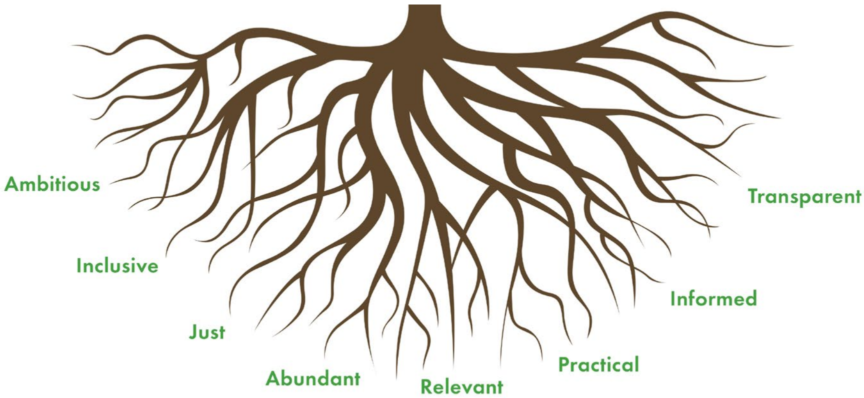


Figure 40. NATURVATION Ensuring Strong Roots for NBS. Source: Bulkeley, 2019

There is then evidence that NBS can achieve some forms of transformational change, but much less certainty that different forms of transformational outcome can be realised simultaneously. To date, transformational processes have, for example, taken place at a small scale with less evidence that they have been able to engender system-wide or structural change. Where system-wide changes have emerged – for example in new legal requirements for the use of SUDS or green roofs – there is little evidence that these have been transformative in terms of either inclusion or in terms of structural shifts in how the benefits of urban development and efforts to address sustainability are shared.

A next step for NBS initiatives and research projects may therefore be to focus on how the different principles that can underpin transformational change can be pursued in tandem to achieve more sustained and significant contributions for sustainability. While many projects have focused attention on the challenge of scaling-up NBS and the potential for mechanisms such as peer to peer learning, regulation, standardisation, emulation and so on to achieve this, a focus on the different underpinning principles that enable NBS to be governed effectively over the long term requires also an understanding of how these different elements may/not be compatible and how processes and mechanisms through which the transformative potential of NBS can be advanced.

9.4. POLICY RECOMMENDATIONS & KNOWLEDGE GAPS (GOVERNING NBS)

Research undertaken by EU-funded projects has extended our understanding of the ways in which NBS encounter challenges in terms of their implementation and governance and the modes of governance through which these can be overcome. While we are now building a picture of how governing takes place at the local level to implement NBS much of this has focused on the urban arena rather than rural environments, the regional scale or across diverse landscapes, and has tended not to scrutinise how changes in multilevel governance – both across levels of government and through horizontal networks - can support the development of NBS. There has also been a great deal of uniformity in how research and innovation has been undertaken with respect of the governance of NBS, with a particular focus on municipal-led and co-production approaches to governance, which may introduce some bias to the evidence base. Nonetheless, it is possible to establish policy recommendations from the work that has been done in this field to date and to identify some key knowledge gaps that could helpfully be addressed through future projects and programmes.

In terms of policy recommendations, it is suggested that:

- There is a strong need to provide support and capacity building for the wide range of modes of governance that are being used to implement NBS. Enhancing regulatory or planning powers alone are unlikely to deliver NBS, given the multiple actors involved in their governance and the challenges of working in-between policy silos and generating effective partnerships. Developing capacities for partnership working and participatory governance, alongside establishing intermediary organisations and platforms through which innovative forms of governance can be established might provide alternatives.

- The governing of NBS is multilevel and requires stronger alignment between different levels of government and the development of stronger 'webs' of horizontal networks. It is important that this is not mistaken for policy integration, given the complexity of NBS and the benefits they provide policy integration is likely to be impossible or extremely costly. Greater alignment through establishing shared goals and visions, communication and coordination between different initiatives will enable NBS to flourish. New horizontal networks are currently being established between cities (such as CitiesWithNature), and lessons from the climate arena tell us that a dense web of alternative different forms of transnational, national and regional network governance can support action on the ground. In short, multiple networks and partnerships are likely to be more effective, even if the resulting governance landscape appears 'messy' to the outside world.

- There is currently little evidence of the development of new tools and techniques for governing NBS, beyond those which focus on the development of knowledge and assessment. It will be critical to foster experimentation with governance techniques including standards, certification, incentives, subsidies and so on that develop private and voluntary governance alongside formal regulatory and planning powers, in order that the full range of actors who might be able to be involved in the governing of NBS are enrolled and NBS can become embedded as 'normal' practice within organisations in the public and private sectors.

- Transformative change may require different approaches for governing NBS than those which have been deployed to date, especially where transformation is seen as involving structural change (e.g. in the form of land ownership or profit generation in an urban context) or where it is intended to address the root causes of social and environmental justice. Such approaches may require new forms of dialogue and experimentation amongst both those who have most responsibility for sustainable development (those with access to power, resources, knowledge and who may currently gain the most from un-sustainable development) and those who may have most rights to the resulting benefits (e.g. including those who are currently living in poor health or with environmental harm). Seeking new forms of 'just transition' for affected communities could be one approach through which more transformative forms of governance can be developed.

- NBS are likely to be contested. Rather than seeking only to foster consensus, governing will require that space is made to air divergent views, to contest decisions and to actively protest against the implementation of NBS. New governance techniques and arrangements that do not seek to manage difference but enable it may be required to fully harness the potential that such forms of friction can bring.

- Successfully enabling NBS to flourish in the future will require going beyond our existing knowledge and understanding of their governance in important ways:

- In comparison to municipal-led and co-production modes of governing, we lack an understanding of how other diverse modes of governing (e.g. private sector, philanthropic, private-civil society partnerships) are emerging in relation to NBS, how they operate and the factors that shape their success or limit their potential.

- Additionally, our understanding of how diverse actors – who may operate at different scales and through multiple networks such as health provision, the insurance sector and institutional investors – are engaged in the development and implementation of NBS. In particular, many land holders (e.g. churches, charitable organisations, educational establishments, utilities) and financial sector actors (e.g. insurance companies, banks who provide mortgages and business loans etc.) are often absent from studies of the governing of NBS. Developing this research may mean moving away from a focus on case-studies and local implementation, towards work on particular groups of actors, sectors of the economy or landscapes.

- Governing for transformative change will require that multiple principles for NBS are embedded in their design, development and management over time. We currently lack an understanding of the synergies and trade-offs between these principles – for example, is it possible for NBS to be both ambitious and inclusive, or might there be challenges in accommodating initiatives that seek to be abundant in generating multiple outcomes and a goal of enhancing transparency through monitoring and evaluation? Further work is required to examine the ways in which such principles can be embedded to support and sustain NBS over time and enable them to become established as normal practice for urban and rural development.

Market challenges and opportunities for NBS

Kym Whiteoak

10. MARKET CHALLENGES AND OPPORTUNITIES FOR NBS

10.1. INTRODUCTION

The European Green Deal (EGD) communication identified the need to strengthen efforts on climate-proofing, resilience building, prevention and preparedness, and notes that “work on climate adaptation should continue to influence public and private investments, including on nature-based solutions” (EC, 2019e). The EGD communication also noted the significant investment is required to achieve its ambition, stressing that investment of this magnitude will require mobilisation from both public and private sectors.

More broadly, strong interest in greater use of NBS has come from communities and governments for many reasons, particularly as the risks to societies and businesses from climate change and biodiversity loss mount. Interest is also growing from a range of potential investors in NBS including impact and institutional investors, private businesses, the insurance sector, banks and philanthropists.

However, developing self-sustaining markets for NBS has proved an ongoing challenge for a range of reasons, most centrally being that easily monetised benefits of individual NBS investments do not clearly exceed costs in many individual cases: NBS investments often produce a mix of multiple benefits (including ecosystem services), some that are difficult to quantify in monetary terms and many that are public benefits that do not produce direct financial revenue streams (see Wild et al., 2017). These benefits may accrue to different stakeholder groups. As a result, funding of NBS has typically focused on a narrow range of public sources.

Much research has been undertaken to identify barriers to market development, as well as identify pathways to overcome them. Additionally, examples from around Europe and elsewhere show how the benefits of many different types of NBS investments can exceed their costs, and that financing from increasingly diverse sources is possible. The H2020 research programme has funded eleven ongoing projects that include NBS demonstration sites that will further contribute to the evidence base of NBS benefits (see section 1).

A Taskforce on Governance, Business Models and Financial Mechanisms (Task Force 3) was created as a collaborative space and clustering channel for all relevant H2020 funded NBS projects. Taskforce 3 collaborates in the areas of business, finance and governance models, within the overriding objective of advancing the development, uptake and upscale of NBS. Some discussions from Task Force 3 are reflected in this document.

In this section we discuss the market for NBS, exploring challenges to market development, potential solutions identified in research, outline business cases and business models for NBS along with case studies, highlight a range of promising solutions, and consider research and policy gaps.

10.2. THE MARKET FOR NBS

The market for NBS consists of those with demand for NBS (buyers) and those supplying NBS product and services to the market (sellers). Understanding this market can assist in better understanding barriers to NBS adoption, as well as instruments and strategies to assist in overcoming those barriers. Significant work has been undertaken to describe the NBS market within the EU, including Naturvation's Urban Nature Atlas of over 1000 urban nature NBS sites across 100 European cities. In relation to demand, analysis by the NATURVATION project has shown that almost 75% of NBS investments in the EU are funded by the public sector (Toxopeus et al., 2020), with responsibility for ongoing management remaining with this sector – NBS assets often form part of the public lands estate of different levels of government.

As evidenced by a willingness to invest, demand for NBS investments from the private sector is far more limited, despite growing interest from the financial sector in green bonds and Environmental, Social and Governance (ESG) investments, due primarily to the limited scale of direct financial revenue produced from NBS assets. As noted, the benefits of NBS assets are often non-financial, or indirectly financial – for example, a benefit of urban greening can be improved air quality, which may take many years to produce financial savings to the healthcare system.[19] Developing investment products on such a basis has proven to be a significant challenge. Whilst a common set of indicators for monitoring the impacts of NBS investments is being developed by H2020 projects, to date less work has been undertaken of quantifying the monetary value of these impacts.

Some assets are more easily funded by the private sector, such as green roofs which add to property values, where benefits clear private benefits can be identified - such as energy use savings from thermal insulation (EEA, 2017), and simple regulatory instruments can be used to promote their use - such as planning requirements for green roofs on new buildings (Center for New York City Law, 2019)

In relation to supply, it is important to consider the scale at which the NBS market exists – rather than a European-scale market, where suppliers operate across national boundaries, suppliers of NBS services often operate within a local market, servicing a market at city or sometimes regional level. Suppliers can provide grey solutions as well as green, and build expertise in NBS provision in response to consistent supply within the market they operate.

[19] In this example, the greening investment may take time to mature and produce the maximum air quality benefit, and the health benefit itself may take additional time to be realized in the health sector

The GROWGREEN H2020 project undertook a survey of market participants in its three lead cities (Manchester, Wroclaw and Valencia), which identified challenges relating to a lack of consistent demand that inhibited market development. Greater awareness of NBS and its benefits was identified as a challenge, and strong support for regulatory requirements for NBS was identified from suppliers, as it provides market certainty (Baroni et al., 2019).

Considerable research has focused on market barriers[20] to expanded NBS implementation, identifying:

- Funding shortfalls limit the demand for NBS from public providers;
- In turn, a lack of consistent demand, inhibits the development of specialist expertise in NBS service-delivery;
- Challenges in procurement that inhibit innovation and can lead to the continued implementation of more 'certain' grey solutions over NBS (see UNALAB, Hawxwell et al., 2019).
- Lack of detailed information on quantified market and non-market benefits of NBS investments inhibits understanding of the full benefits of NBS.
- Information and capacity gaps on NBS options and their effectiveness limits their selection compared to grey solutions.
- Governance challenges for organisations that may have a 'siloed' approach to decision-making, in managing multi-functional green space.

A range of solutions and pathways have been identified in research, to help overcome these barriers. For example[21], in urban NBS:

- Adopt a Total Economic Value (TEV) approach to economic assessment of NBS options, to ensure that the full range of benefits are considered. A TEV approach assesses all benefits of an investment, not simply the direct financial flows (Hawxwell et al., 2018).
- Development and greater use of financial instruments such as green bonds[22] and blended finance for NBS.
- Adopt regulatory requirements that encourage consideration of NBS in decision-making, such as a requirement to demonstrate that NBS options were explored in decision-making on flood mitigation measures, urban biodiversity no net loss / net gain regulation, or compulsory green roofs in new buildings (Whiteoak et al., 2020).[23]
- Foster capacity-building of NBS principles and practices for relevant decision-makers in NBS-related fields (Hawxwell et al., 2018).
- Position NBS as a mainstream climate change adaptation (CCA) intervention.
- Develop governance mechanisms that allow for coordinated funding of NBS.
- Develop and apply knowledge tools that offer indicators, evidence, transparency and monitoring of NBS

[20] This list focuses predominantly on market barriers. Governance barriers are addressed in section 9.
[21] Unless otherwise noted, remaining pathways come from NATURVATION.
[22] As per UNaLab, Deliverable 6.2 Municipal Governance Guidelines, green bonds can serve as means for cities to secure funding for NBS (Hawxwell et al., 2018). So far green bonds on municipal level have been deployed to finance projects on, for example, climate change adaptation, energy efficiency and renewable energy, sustainable land use, agriculture and forestry, biodiversity preservation, waste management or clean water. Municipalities can consider four types of green bonds (general obligation, revenue, project, securitised).
[23] In many jurisdictions it is required that new regulations first be demonstrated to be in the public interest, meaning the business case for these requirements would need to be made.

- Include urban NBS into institutional investment portfolios through regulatory and supervisory action and certification schemes
- Actively engage the (re-)insurance sector as the 'missing link' in upscaling NBS
- Increase the cost effectiveness of NBS investments by integrating them into planned infrastructure and real estate projects.[24]

Additionally, research has also been undertaken on specific categories of NBS market segments, such as the insurance and re-insurance sector (discussed below)

10.3. THE BUSINESS CASE FOR INVESTMENT

The term 'business case' for NBS investment refers to data demonstrating that the benefits of NBS investments exceed their cost, within an attractive payoff period. While direct financial revenues and costs are typically considered in a cost-effectiveness assessment within a business case, the scope of a business case need not be restricted to this narrow definition, as many investors (particularly public sector ones) invest based on a broader 'whole of society' economic assessment, considering the full range of costs and benefits of an investment. Public investors may also consider longer investment timeframes than do private investors. Regardless, developing the business case for investment in NBS poses a challenge to NBS practitioners for a number of reasons:

- The performance of NBS solutions are sometimes less precise than their grey alternatives. For example, using GI such as swales or bioretention to naturally remove pollutants from rainwater can have more variable performance compared to mechanical treatment in combined sewer systems.

- NBS investments are often designed to use or fit within the natural environment, and their performance in turn is affected by local conditions (such as rainfall, temperature, e.g. Stovin et al., 2012). This limits the ability to develop general information about NBS performance, and also means business cases must be developed specifically for each investment, making awareness-raising of NBS more challenging.

- NBS investments often produce multiple benefits in varying scales (e.g. Gomez-Baggethun & Barton, 2013; Barton, 2015; Wild et al., 2017), which makes measurement challenging (see Figure 41 below). For example, a green courtyard might produce rainwater treatment, heat reduction, contribute to physical and mental health, and be designed to allow the production of fresh produce from community gardens. Alternatively, the same space could be used as a car park with more easily measured revenues.

- Related to the above, a lack of data on the scale and nature of NBS benefits in certain contexts remains a significant challenge. Some benefits are more easily measured

[24] Analysis from the NAIAD project finds that reinsurance (whereby insurance providers purchase their own insurance to mitigate risk) may be a potential source of private sector investment in NBS related to flood mitigation (Rica et al., 2017)

(such as rainwater diverted from sewers from swales), while others are far more difficult to quantify in physical and monetary terms (such as heat reduction from urban green space or mental health benefits from urban greening). The NATURVATION Project has compiled a database of 205 economic valuation estimates from 105 studies on NBS investments from around the world, and a forthcoming paper from the same study aims to produce consistent value metrics for selected NBS types and functions (Bockarjova & Botzen, 2017).

- Also related is the fact that many benefits of NBS are non-financial in nature (in that they do not provide direct revenue streams) and are difficult to attribute to a specific entity. For example, the planting of street trees will contribute to local air quality and the shade will contribute to urban cooling – while these benefits can be quantified (with difficulty), there is no direct revenue to whoever may plant the trees, and it is difficult to identify a specific entity that might pay for this long term benefit. Continued work in natural capital accounting may assist in building defensible data in this area.

- The return on investment (RoI) timeframe for NBS investments may be long and uncertain, depending upon the category of NBS. For example, while the use of agricultural land as a detention basin for flood mitigation can be designed to provide full value in year 1, other NBS that provide shade and physical and mental health benefits may not produce meaningful benefits until years after the initial investment.

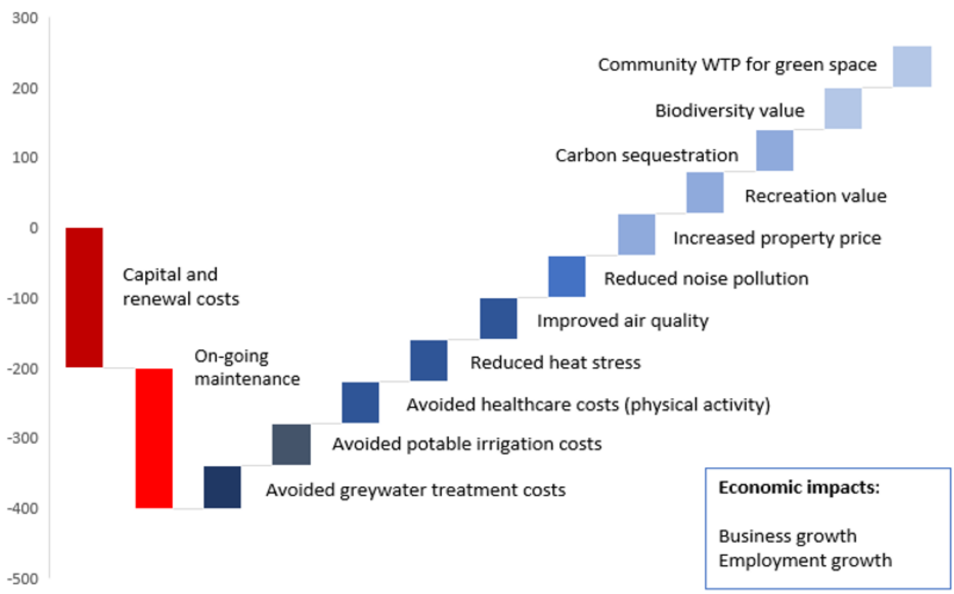


Figure 41. Illustration of costs (red) and multiple benefits (blue) of NBS demonstration project in Valencia, Spain (GrowGreen, 2019) [25]

[25] Business and employment growth, while significant outcomes of NBS investments, are classified as economic impacts rather than measures of economic benefit.

While many benefits of NBS are 'non-market' in nature (in that they are not traded in conventional markets), they can in many cases be measured and monetised using economic tools. These have been described in some detail in H2020 projects such as NAIAD (Deliverables 4.3 and 4.4) (Calatrava et al., 2018; Hérivaux, Le Coent & Gnonlonfin, 2019) and FP7 projects such as OPENNESS (Barton et al., 2017).

Although not a measure of economic 'value' in a formal sense, NBS investments also produce economic impacts such as commercial activity and employment, both directly – through design, construction and maintenance of investments, and indirectly – such as by stimulating economic activity (BenDor et al., 2015). These elements are important to decision-makers in relation to funding, and can be used as inputs to financing strategies as commercial benefits can justify private business co-contributions to NBS investments.[26] The current H2020 projects involving demonstration projects will contribute useful information on employment and commercial activity associated with NBS investments.

Figure 42 presents some data assembled from a survey of nature-based enterprises (NBEs) for the Connecting Nature project, which found growth in the number of nature-based enterprises over time.[27] The same survey found that 98 percent of NBEs are small and medium-sized enterprises (SMEs) and that the vast majority had an annual turnover of less than two million euros.

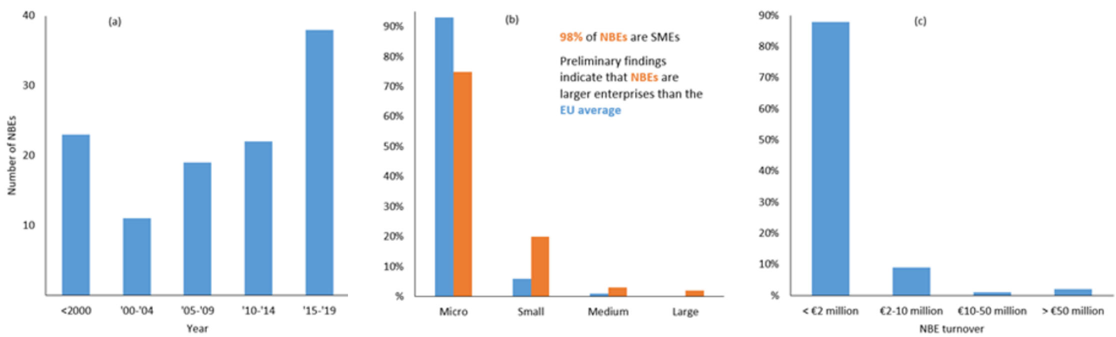


Figure 42. (a) Number of new NBE created; (b) Proportion of NBE created per size of enterprise; (c) Turnover of NBE created (Connecting Nature, 2020b).

[26] BFor example, 'Business Improvement Districts' can be defined whereby private businesses co-contribute to NBS investments that may attract visitors and lead to greater commercial activity (described further in Table 27)

[27] The survey was conducted in January 2020, and elicited 113 responses from 22 countries (86% from Europe, 14% from elsewhere).

BOX 62. EXAMPLES OF BUSINESS CASES AND BUSINESS MODELS FOR NBS

Flood retention in Austria: An expensive investment in conventional 'grey' infrastructure for flood mitigation was avoided in alpine Austrian municipality Alternmarkt by instead altering the flow of the Enns River upstream of the town, allowing it to temporarily flood agricultural land in periods of high flow. By paying agricultural land-owners for this ecosystem service, significant cost savings were generated at a benefit-cost ratio of 3.6 (that is, €3.6 in benefit for ever €1 spent). In addition, beneficiaries of reduced flood risk in downstream Alternmarkt also directly contributed to the up-front and ongoing costs of the project, providing an innovative business model for the project.

Flood mitigation in Rotterdam: The NAIAD project compared green and grey options for flood mitigation in suburban Rotterdam, exploring a green option for rainwater retention that reduced rainwater discharge to the sewer system and could be used for irrigation purposes. On directly financial comparison, the analysis found that the NBS option could be delivered at a 15% saving compared to the grey option. When considering additional co-benefits (i.e. health impacts, property price increases, heat mitigation, roof lifespan extension and potable water savings), these benefits were estimated at 55% higher than the direct flood mitigation benefits.

Green roofs financing business model: Dutch insurance company Interpolis has developed a model for centralising the process for residential green roof assessment and installation, arranging initial roof inspections, organising construction and arranging applications for municipal subsidies. This approach minimises transaction costs, reduces implementation costs through economies of scale, and achieves flood mitigation benefits to the municipality, reduced exposure to insurance claims to the insurer, and savings to the household produced from the green roof, such as reduced cooling costs in summer (Toxopeus et al., 2020).

The NAIAD project produced a general methodological framework (Graveline et al., 2017) for assessment of NBS investments in the context of flooding and insurance. This framework acknowledges that in practice no singular economic method can be applied in the same way for every project, due to differences in context, stakeholders, regulatory structure, resources, data availability, expertise, biophysical context, existing infrastructure, and previous approaches to managing risk and resilience. This is true for NBS more broadly. The UNALAB project also proposed the use of a Total Economic Value framework for assessing the full range of costs and benefits attributable to options, to account for the multiple benefits of NBS project (Hawxwell et al., 2018).

While some valuable work has already been done, there remains a clear need for additional work demonstrating the multiple benefits of different NBS investments in different contexts, and the monetisation of these benefits using rigorous methods. The eleven current H2020 projects involving demonstration projects provide an invaluable opportunity to produce detailed assessments of NBS benefit estimations and business cases.

10.4. BUSINESS MODELS

A business model refers to the organisational structures designed to produce a commercial opportunity (George & Bock, 2011). For NBS, therefore, the business model is the organisational structure that enables sustained implementation of NBS investments, including ownership, operation, and financing. As noted above, the significant majority of NBS investments are financed with public funds, and private sector investment models are identified as a key component of expanding the use of NBS across the EU. Defining and implementing sustainable NBS business models for has been the focus of much research, with many projects such as CONNECTING (2020) detailing the major challenges to innovation in NBS financing and business models:

1. Focus on capital investment without considering the sustainability of the NBS business model. Who will pay for the NBS after the capital investment phase?

2. Path dependency on the same sources of financing for NBS, which are mostly funded from public sources (city, regional, national, European). The pressure to meet disparate public funding requirements has led to the emergence of projects with competing or incompatible objectives.[28]

3. 'Silo' gaps: Internally there is a lack of financial planning and business model expertise in the environmental and planning department. There is often mis-alignment between public sector departments e.g. economic and tourist objectives c.f. environmental and planning objectives. The interests of external stakeholders, beyond immediate residents, are often unexplored.

4. Lack of experience in using public procurement to stimulate new innovations/markets.

5. Pressure to pursue public-private partnerships without considering social or environmental trade-offs.

6. Complexity of governance hindering innovation in business models: NBS often involve multiple public agencies, NGOs, residents and other stakeholders, and it can be difficult to align different interests to reach a common vision and engage stakeholders in ongoing governance and business model arrangements.

A number of tools have been developed within H2020 projects to assist decision-makers and planners to identify and consider alternative business models for NBS:

[28] That is, NBS projects may have to remove or alter key NBS aspects in order to attract funding from sources that have competing objectives.

GrowGreen Catalogue of NBS Financing Approaches (Baroni et al., 2019): this document details a range of financing mechanisms that have been used by public sector entities within Europe and beyond, to finance NBS investments. A description of each option is provided, together with contextual information (prerequisite conditions and limiting factors), along with one or more case study examples of the option in practice. Financing mechanisms are categorised broadly into those designed to implement NBS projects directly, and those to encourage other actors to implement NBS or to contribute to the maintenance of NBS in the public domain. A short synopsis of the document can be found below (see Table 27).

Naturvation Business Model Catalogue (Toxopeus, 2019): this document describes eight different models for NBS implementation and funding, each designed around a different context and therefore involving various potential funding approaches. The document considers four different aspects of each model (value proposition, value delivery, value capture and enabling conditions & risks), with associated case studies, providing readers with ideas for alternative funding strategies and real case studies to demonstrate the ideas in practice.

Connecting Nature NBS Business Model Canvas: this guidebook is designed to assist planners and decision-makers in cities to visualise a business model for NBS investments, drawing from the original Business Model Canvas developed by Osterwalder et al. (2005). The tool invites users to consider the 'value proposition' of the NBS investment (what the customer or end-user wants), 'value creation and delivery' (who is needed to create and deliver the value proposition), and 'value capture' (how much will it cost, and how to pay). The process allows participants to incorporate broader environmental, social and economic considerations into decision-making. A similar approach was developed specifically for water risk reduction NBS by NAIAD (Graveline et al., 2017).

TABLE 27. SUMMARY OF NBS FINANCING INSTRUMENTS AVAILABLE
(Baroni et al., 2019)

TYPE OF INSTRUMENT	DESCRIPTION & INSTRUMENT – SPECIFIC EXAMPLE (WHERE AVAILABLE)		CASE STUDY
Innovative use of public budgets	Pool funding from departments of local authorities Attracting funding from the public health budget Greening of hospital estates Police budgets Education budgets		Natural Choices for Health and Wellbeing programme, Liverpool Forest Sports Zone, Nottingham Grey into Green programme, Wroclaw
Grant funding & donations	Local authorities provide grants for GI creation and maintenance	European Structural and Investment Fund (ESIF)	Grey to Green Project, Sheffield
		Programme for the Environment and Climate Action (LIFE)	The Urban Adapt
		Horizon 2020	e.g. GrowGreen
		Regional and national government grants	Big Lottery Fund Heritage Lottery Fund
		Philanthropic contributions	The Royal Parks Foundation
		Crowdfunding	Ghent crowdfunding platform for climate adaptation
Instruments generating revenue		Land sales / leases	
		Taxes	Renaturalisation of the Wesser Rivers coast
		User fees	Botanic gardens and parks
		Developer contributions / charges	Development Cost Levy, Vancouver
		Betterment levies	Levies on residents in proximity to parks, UK
		Voluntary beneficiary contributions	
		Sale of development rights and leases	

TYPE OF INSTRUMENT	DESCRIPTION & INSTRUMENT – SPECIFIC EXAMPLE (WHERE AVAILABLE)		CASE STUDY
Instruments generating revenue *cont.*		Funds linked to offsetting/compensation	Ruhr river renaturation, Arnsberg, Germany
		Other voluntary schemes	Carbon compensation scheme for tree planting in Bologna, Italy
'Green finance' (debt instruments)	Loans		
	Green bonds		City of Gothenburg Green Bonds Climate Adaptation Bond Paris
	Natural Capital Financing Facility (NCFF)		Athens Resilient City and Natural Capital
Market-based instruments	Instruments using markets to provide incentives for private parties to invest in NBS	User charges	Deployed in Hamburg & Manchester
		Taxes	
		Subsidies	Scheme for rainwater management installations, Bratislava
		Tax rebates	Tax relief for Natura 2000 private land management, France.
		Credit-trading system	Stormwater Retention Credit Trading Program, Washington, DC
		Offsets (e.g. biodiversity offsets or habitat banking)	Pilot biodiversity offsetting programme, England
		Payments for Ecosystem Services	Woodland Grant Scheme, UK
Business improvement districts	Business enter into agreements with local authorities to provide additional finances for improvements in a specific area.		Team London Bridge, UK
			Lower Don Valley Flood Defence project in Sheffield, UK
			Green Benefit Districts in the US

TYPE OF INSTRUMENT	DESCRIPTION & INSTRUMENT – SPECIFIC EXAMPLE (WHERE AVAILABLE)	CASE STUDY
Endowments	A fund established through e.g. donations, the interest from which are used to pay for the maintenance of green infrastructures.	The Land Trust, UK
		The Parks Trust, UK
		Sheffield Endowment Fund
Public – private partnerships	Long-term contracts between a private party and a government entity, for providing a public asset or service, in which the private party bears significant risk and management responsibility.	Public Private Partnership for a flood-proof district in Bilbao, Spain
		Oxley Creek, Brisbane, Australia
Revolving funds	These are funds that are replenished through repayments of the loans drawn from the fund or by a constant flow of financial contributions.	Clean Water State Revolving Fund, USA
Community asset transfer	Local authorities can transfer the management and/or ownership of public land and/or buildings. If certain conditions are fulfilled, these transfers can, in some countries (e.g. UK) be made below market value.	‘Beyond the Construction Site’ - Community-based gardening in Ljubljana, Slovenia
Regulation & planning standards	Local authorities can deploy these to mandate GI implementation by private stakeholders.	Biotope Area Factor (BAF), Berlin, Germany
Leveraging existing regulatory requirements	Entities with environmental obligations can leverage the requirements to invest in NBS’.	Wetland filtration of wastewater, River Ingol, England

Furthermore, a number of products and other solutions have been developed in recent years that may support the implementation of NBS (Table 28).

TABLE 28. PROMISING SOLUTIONS AND TECHNOLOGIES ENABLING NBS UPTAKE
A technological system developed in **Aarhus**, Denmark, involving real-time control of a full urban water cycle with sewers and wastewater treatment plants as well as recipient waters such as lakes, river, and a harbour. The aim of this real-time DSS system was to adapt Aarhus' water system to climate change related challenges and to raise the recreational potential in the city of Aarhus via an improvement in water quality. The system is designed to minimise combined sewer overflows (CSOs) which can occur during large rainfall events, and includes CSO storage basins, additional treatment capacity at wastewater treatment plants (WWTPs), and automated control of a network of pumps, gates, and weirs. The system is designed to reduce CSO spills during storm events through better management of storages, and was implemented to improve water quality in the Aarhus River, the upstream Lake Brabrand and the Aarhus Harbour (DHI, 2017).
The **Eco:Actuary** tool is a freely available spatial probabilistic flood risk model that creates on-demand flood risk, flood mitigation and damage estimate maps for current conditions or scenarios for climate, land use and land management. The system is designed to work in collaboration with the //Smart: system of intelligent sensors, which are low cost, DIY, web connected sensor systems designed to cheaply and effectively assess the impact of natural capital, NBS and natural flood management interventions in the field. The hardware connects to a series of online tools for localising outputs, effectiveness assessment of interventions or early warning. This tool was developed with NAIAD.
Within the PHUSICOS project, a novel approach to **stabilisation of steep mountainside moraines** is being tested, to address rock fall, debris flow and landslide challenges following glacier retreat and exacerbated by climate change causing an increase in extreme weather events. The approach is an interdisciplinary effort between geomorphologists and ecologists and uses vegetation and bacteria to enhance plant traits that most strongly contribute to slope stability. Their use will not only contribute to the primary goal of landscape stability, but also add biodiversity and produce socio-economic benefits.
As reported in section 4 (Biodiversity), **sown biodiverse pastures** are a system of pastures developed by Terraprima. They contain a mixtures of a large varieties of seeds containing a high proportion of legumes and can generate higher yields than those occurring naturally in seed systems. They constitute an alternative agricultural system that optimises both the economic and environmental performance of farms and are relevant for areas susceptible to agricultural abandonment and desertification.

In conclusion, NBS investments are many and varied, with their benefits and costs differing by project type and context. They produce a range of benefits, many of which are public goods that produce limited revenue streams, and may accrue to different stakeholder groups. Detailed understanding of these benefits remains somewhat lacking. These features make financing of NBS projects perpetually challenging and investment from the private sector particularly so.

Nevertheless, in many cases NBS investments can be shown to be efficient investments from a 'whole of society' perspective, and sometimes are preferred to alternatives from a direct financial viewpoint.

The research agenda can be used to help fill gaps in our knowledge about the biophysical, economic and financial performance of NBS investments, and in trialling the development of business cases and business models for NBS implementation.

In relation to engagement with the private sector on NBS, despite the sector's interest in investing in NBS it is clear that a measurable return on investment is required for this interest to translate to implementation. Where it is directly financially viable to do so, investment from the private sector can be relied upon. However, where benefits are less direct, more variable or long term, private sector investment will remain less likely. In such cases, the public sector has many powerful tools at its disposal to influence behaviour, through grants, regulation, taxation and market development. These can be used to produce outcomes that are demonstrated to be in the public interest.

10.5. GAPS & FUTURE WORK FOR RESEARCH & POLICY (MARKETS FOR NBS)

Overcoming the economic and financial challenges of upscaling NBS is not simple task that can be resolved in the short term. Many benefits of NBS will continue to be public goods, with long payoff periods, limiting their interest from private investors. Thanks to the research that has already been undertaken on NBS including from recent and current H2020 projects, a detailed understanding has been developed of barriers to NBS upscaling and pathways to greater implementation of them. Nevertheless, some key gaps in research remain and investment could be directed to address these gaps:

- *Quantification and monetisation of NBS benefits:* a comprehensive understanding has not yet been developed of the nature and scale of NBS benefits in different contexts and modes of implementation. Quantification of these benefits in monetised form will be highly valuable for the development of business cases and business models. The eleven current H2020 projects containing demonstration projects provide a perfect opportunity to monitor, measure and monetise a range of NBS benefits, which can then be used for this purpose. Future projects that focus on filling key gaps in benefit data through demonstration projects can provide great value in building this knowledge base.

- *Methodological guidance on assembling NBS business cases*: as noted above in this document, the practice of assembling a business case for NBS will differ by context and as such a simple 'tool' for implementing economic analysis of NBS benefits and costs may not be helpful. However, guidance on a methodological approach to applying a Total Economic Value framework to NBS projects may be of practical use to practitioners in making the case for NBS investments.

- *Building and testing financial instruments:* to the extent that the finance sector may invest in NBS, using debt instruments appears to be the most likely method of investment. As such, work on developing NBS 'green bonds' at appropriate levels (e.g. European cities) may be beneficial, perhaps in collaboration with the European Investment Bank or other relevant agencies. More work clarifying the potential of private sector investors to invest in NBS in general would be beneficial.

- *Development and implementation of multiple beneficiary projects:* NBS projects often produce a mix of public and private benefits that may accrue to different stakeholders. Therefore, one valuable research approach would be to implement studies that identify potential NBS projects, undertake analysis exploring their costs and benefits, develop financing strategies and then secure financing for implementation of those projects (with the acceptance that some may not succeed). This would generate valuable insights about good processes to follow in NBS project development, and a strong understanding of the work needed in practice to guide these projects to implementation. Successful projects would demonstrate to interested parties that multiple-benefit, multiple-funded projects are possible to implement.

These ideas are relevant to research and are also relevant to policy-makers. Additionally of interest to policy-makers are the following suggestions:

- *Good economic analysis may reveal cost-effective NBS options:* as several H2020 projects have demonstrated, robust economic analysis considering the full range of costs and benefits of options from a 'whole of society' perspective is a useful tool to inform decision-making in relation to NBS. Benefits may be directly financial, but are more often avoided costs to public entities that may otherwise make grey investments, or public benefits to sectors that may not be directly related to the project (such as public health). Rigorous use of economic analysis that include consideration of NBS options may reveal more NBS options than would otherwise be identified. Ensuring that decisions made in all sectors that may use NBS options use a rigorous 'Total Economic Value' (TEV) framework for assessing options would be a strong policy development.

- *Combine public and private funding sources:* NBS projects most often produce a mix of benefits of which some are public and others private. It is rare that NBS projects produce a significant private financial revenue stream that justifies the costs of an investment. Therefore, it may be accepted that public funds may be used to secure public benefits, and leveraged to secure private funds for private benefits. To expand the implementation of NBS projects, the use of competitive tenders that combine public and private investment might be useful, in which projects are awarded public funds based on the highest value produced from the investment of public funds (among other objectives). This may be a useful way to engage the private sector that *has hitherto been reluctant to invest in this space.*

- *Regulation and market-creation:* the private sector responds to clear incentives and market certainty. Therefore, where government is confident that benefits of certain actions exceed their costs, they can introduce regulation that obligates a certain outcome or action. This could be as simple as requiring that NBS options be meaningfully explored in flood management planning, to requiring the implementation of green roofs on new developments. The risk of regulation is of course that poor investments may be inadvertently produced; this means that appropriate analysis and collection of evidence must be used to underpin any such requirement.

Further work in these key areas could greatly assist the development of NBS implementation in Europe.

TABLE 29. BUSINESS CASES AND BUSINESS MODELS: DETAILED EXAMPLES

(a) Alternmarkt flood retention in Austria (Löschner et al., 2019)

Altenmarkt is an alpine municipality in Austria with 4 200 inhabitants at significant risk of flooding from the local Enns River and one of its tributes, the Zaubach Torrent. Altenmark is an alpine municipality located on a valley floor, and with only 22 per cent of municipal surface available for permanent settlement, the options for flood mitigation intervention by conventional means are similarly limited.

In response to increasing flood risk, between 2013 and 2016 a flood defence project was implemented along the Enns River, with the aim of protecting the Altenmarkt municipality from a '100-year flood'. The project includes linear measures (approx. 3.5 km in length) as well as an innovative NBS measure that 'borrows' 20 hectares of existing agricultural grassland upstream of the town as a retention basin which is activated when flood discharge exceeds a threshold equivalent to a '35-year flood'. When not otherwise required, the agricultural land can be used for its pre-existing purpose, and the land owners are paid a yearly compensation for inconvenience and the limitations it places on land use.

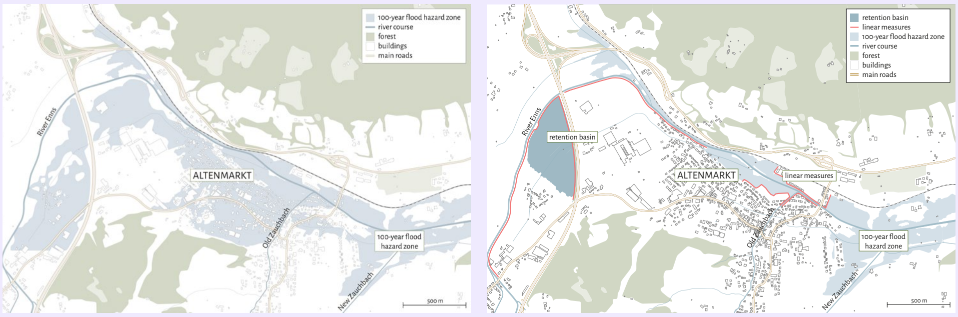


Figure 43. Demonstration of the impact on flooding of the project (Löschner et al., 2019).

The total project cost is estimated at about EUR 9.4 million, benefits of reduced flood damages to buildings and surface areas have been estimated at EUR 34 million, producing a very favourable benefit-cost ratio of around 3.6.

Based on existing management responsibilities, costs for the intervention were split between the federal state (bearing 84 per cent of total costs), and the municipality (bearing the remaining 16% of the costs.

The municipality came up with an innovative business model to cover its share of the project costs. On the basis of past experience with flooding local flood projects, the municipality decided to only finance a part of the project (EUR 400 000), with the remaining share (EUR 864 000) to be financed by the direct beneficiaries of the project, applying a beneficiary-pays approach. The municipality established a water cooperative within the '100-year flood' zone and those landowners within the flood zone who were to benefit from the project were invited to join the cooperative.

The scale of financial contribution of all members of the water cooperative was based on land value, the type of land use as well as the averted flood damage based on the building type and structural features. The beneficiaries were required to pay a one-time fee to finance construction costs but also to provide annual financial contributions for maintenance costs. Furthermore, some land owners benefited indirectly from the project due to the rezoning of open land into building, and were required to provide a share of the appreciated land value as a reserve for future compensation payments. In order to be able to realise the project, it was required that the biggest owners of the agricultural land needed for the flood retention project provide their consent. It was agreed that they receive annual financial compensation, which was to also be financed from the annual budget of the water cooperative.

(b) NAIAD flood mitigation in Rotterdam (Pengal et al., 2017)

One of the case studies developed within the NAIAD project concerned flood mitigation in a suburb of Rotterdam, Spangen. Here, a NBS is to be implemented which would

would expand rainwater retention while reducing rainwater discharge to the sewage system. The neighbourhood currently does not have sufficient rainwater retention capacity, which is problematic during extreme rainfall events, which are expected to become more frequent in the coming years. At the same time, the neighbourhood is also vulnerable in relation to drought (e.g. heat stress or degradation of foundations of buildings). As such, the municipality of Rotterdam has concluded that the neighbourhood requires additional 5 3000 m^3 of water retention capacity.

To meet the need for the retention capacity, the municipality has prepared a water plan for the neighbourhood. Part of this plan was a realisation of a pilot project 'Urban Water Buffer' (UWB) around a local football stadium. The UWB would rely on subsurface storage in which water will be collected and stored during heavy rainfall events. Also, rainwater runoff from the roof of the stadium and from surrounding areas would be collected, treated and recovered for irrigation. The project is expected to result in increase of the retention capacity of the neighbourhood by 1 500 m^3, which can contribute to flood as well as drought mitigation.

The project assessed three different options in relation to the case study of Rotterdam:

I. Grey, being separated sewer system and permeable pavement;
II. Hybrid, being separate sewer system with natural retention and infiltration at public squares, including aquifer storage; and
III. Green, being only green infrastructure for retention and infiltration.

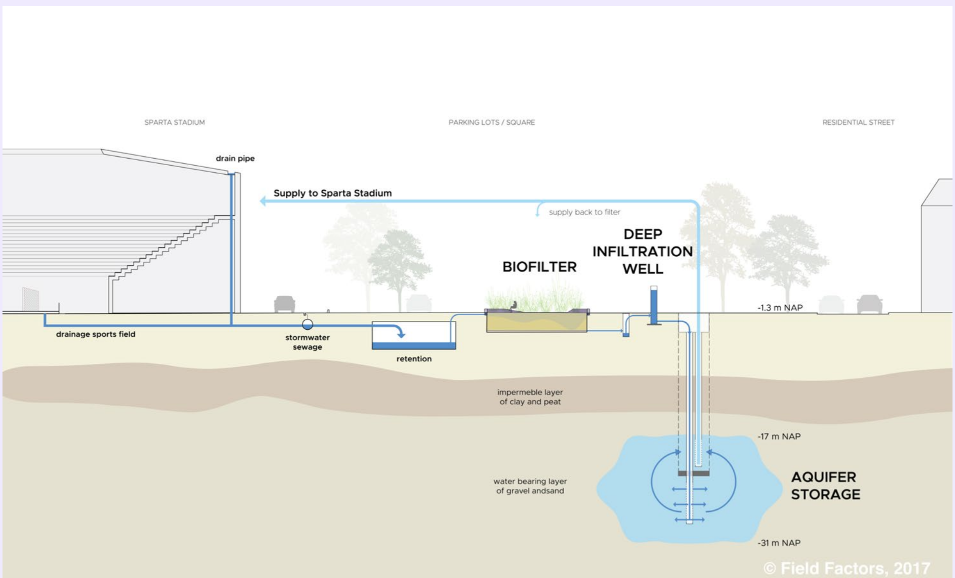


Figure 44. Schematic of proposed NAIAD project, Spangen (Field Factors, 2017).

Critically, the analysis considered not just direct financial costs and benefits relating to the primary purpose of flood mitigation (which were designed to be equivalent in each option), but also considered a range of co-benefits that the NBS options produced. These co-benefits included health impacts, impacts on property values, heat mitigation, roof lifespan extension (for green roofs), and potable water system savings from water reuse.

The analysis found that the cost of implementation of grey solutions was higher (by 15%) than of NBS for the same level of risk management – therefore NBS are likely to be more cost-effective than grey solutions. Additionally, the co-benefits of the green option were estimated to be 55% higher than the flood mitigation benefits, making an attractive case for investment.

(c) Green Roofs and insurance in the Netherlands (Toxopeus et al., 2020)

The insurance industry has the potential to build innovative models around NBS. As an example of an innovative model, a Dutch insurance company (Interpolis) has taken up an innovative business programme to finance green roofs.

Municipal subsidies are available for installing green roofs in the Netherlands, however knowledge barriers are limiting the number of roofs installed. The Interpolis programme involves the insurance company using scale and efficient administration to minimise the transaction costs associated with residential users assessing and contracting green roof installations. Interpolis provides support during the entire process of implementation of green roofs, providing free initial roof inspection, to assess the potential for a green roof installation for each dwelling, and continues throughout its actual implementation. That means that Interpolis provides a contractor responsible for the installation of the green roof as well as a competitive price, which it can deliver due to its collective buying power. The guidelines it provides to residents streamlines the process for applying for a subsidy from the municipality.

The end result of the programme is that residents receive a simplified and subsidised process for green roof installation, the municipality achieves flood mitigation benefits from the green roofs, and the insurance company also estimates savings to individual household damage costs from green roof installation, providing a temporary 10 per cent discount on insurance premiums to participating households. From April to December 2019 the programme produced 30,000 m^2 of green roofs, representing around 1/6 of total installations in the Netherlands. The programme is being integrated into the company's regular service offering in 2020, and expanded to larger and multiple roofs.

Research & innovation priorities in Horizon Europe and beyond

Tom Wild

11. RESEARCH & INNOVATION PRIORITIES IN HORIZON EUROPE AND BEYOND

11.1. BACKGROUND AND CONTEXT

This section highlights needs for future research and innovation in the field of NBS, and in particular, gaps and priorities for Horizon Europe. The scope covers recommendations for programme development and project funding linked with the following themes, amongst others: biodiversity strategies; climate mitigation and adaptation; EU cohesion policy (including just transitions); NBS in rural and urban contexts; and circular economy (including pollution control). An introduction to this evolving research and innovation landscape is provided, followed by an analysis of relevant future priorities linked with NBS.

The European Green Deal (EGD), launched in December 2019, represents a comprehensive review of current sustainability and environmental policies in the EU. It also introduces new legislation to meet the EU's 2050 net zero carbon target, and touches on every aspect of EU activity to address climate change challenges. The EGD will undoubtedly have many implications for research and innovation (as will the recent COVID-19 outbreak and its far-reaching impacts). The EGD is accompanied by many important funding opportunities, policy initiatives and other developments, in the following areas:

1. Increasing the EU's climate ambition for 2030 and 2050;
2. Supplying clean, affordable and secure energy;
3. Mobilising industry for a clean and circular economy;
4. Building and renovating in an energy and resource efficient way;
5. Accelerating the shift to sustainable and smart mobility;
6. 'Farm to Fork': a fair, healthy and environmentally-friendly food system;
7. Preserving and restoring ecosystems and biodiversity;
8. A zero pollution ambition for a toxic-free environment.

The EGD is a key policy driver in the Horizon Europe programme's development, with at least 35% of the budget contributing to climate objectives. Significant amounts of funding are also to be made available for EGD projects in the last years of H2020. It is anticipated that this tranche will total around €1 billion, with many of the priority topics being of great relevance to NBS and associated innovation. The ambition is to facilitate transformative change and thus future projects can be expected to go well beyond technical demonstration. The instruments will remain the same, i.e. RIAs, IAs and CSAs. Calls cover the EGD policy areas mentioned here. A further two 'supporting sections' complement those eight impact-focussed themes of the EGD, by funding actions to improve engagement and knowledge of consumer behaviour and individual action, as follows:

9. Area 9: Strengthening our knowledge in support of the EGD
10. Area 10: Empowering citizens for the transition towards a climate neutral.

The EGD's objectives will inform 'Global Clusters' under the second pillar of the upcoming Horizon Europe programme (2021 - 2027) as well as dedicated funding under the 'Innovative Europe' pillar. Furthermore, four of the five agreed 'mission areas' in Horizon Europe directly support the EGD implementation, as set out below:

- Healthy oceans, seas, coastal and inland waters;
- Climate-neutral and smart cities;
- Soil health and food;
- Adaptation to climate change and societal transformation.

The EU NBS research and innovation community is strategically positioned to provide much-needed responses across many of these thematic areas and cross-cutting challenges, as demonstrated in sections 3-8 of this report, and as highlighted by the growing interest in NBS set out in the introduction section.

11.2. KNOWLEDGE GAPS & PRIORITIES FOR FUTURE RESEARCH & INNOVATION IN NBS

The EC has analysed information about gaps and priorities from existing NBS projects, as well as seeking input from other stakeholders on the development of future programmes. In this final section, that material was supplemented with experts' suggestions drawn from the sections on biodiversity; water quality and waterbody conditions; floods and coastal erosion; climate mitigation; microclimate mitigation and air quality; sustainable communities; governance; and markets for NBS. Broadly speaking, research and innovation gaps reported to the EC included newly emerging priorities, but also some needs highlighted in earlier calls within the H2020 programme, which remain centrally important to N BS uptake. Knowledge gaps and priorities identified by stakeholders can be classified as follows:

1. general calls for investment in R&I into NBS and underpinning research;
2. policy- and governance- research involving social sciences and humanities;
3. technically oriented scientific research, e.g. involving quantitative data;
4. policy development and associated advocacy promoting NBS implementation;
5. co-production and trialling of educational programmes and initiatives;
6. application of economic and financial instruments (loans, investments); and
7. development and testing of decision support systems, tools and models

11.2.1. General calls for investment in R&I into NBS and underpinning research

Several organisations and individuals appealed for longer-term monitoring and evidence on the effects and impacts of specific types of NBS. The need for insights into the mechanisms through which NBS provide services (including synergies and antagonistic effects) was highlighted. Furthermore, calls for funding of research into NBS outcomes were linked with the need for further investment into the development of knowledge hubs and resource centres. Comments analysed generally indicated nuanced understanding that effectiveness of NBS depends greatly on local conditions and this reflects a move away from earlier interpretations of aspirations for direct replication and transfer of NBS innovations (e.g. frontrunner-follower 'transplantation' models).

Calls for NBS design standards and guidance are not new, and are often linked with purported knowledge gaps around technical aspects (e.g. see Qiao et al., 2018, quoted in Vojinovic, 2020). However, other commentators have stressed that sufficient technical knowledge on the design of specific NBS types now exists. There is certainly a need to move beyond seeing the implementation challenge as primarily a 'technical' issue, to develop our understanding of the economic, social, political and cultural dimensions of designing and implementing NBS (Bulkeley, section 9 of this report). Nevertheless, knowledge gaps do exist in relation to NBS design, and particularly different types of plants incorporated, to understand their impacts on environmental quality and health (Calfapietra, 2020; Naumann & Davis, 2020; Wild, 2020). Furthermore, greater attention should be given to the longer-term cycle of NBS performance and impacts, from planning and design through to maintenance and stewardship (e.g. Randrup et al., 2020).

11.2.2. Policy- & governance related research involving social sciences & humanities

Feedback about governance and policy research suggests further work is needed to explore the tensions between and relative success of co-creative c.f. institutional models for NBS implementation. This represents the recognition of divergence in understandings of NBS governance, management and stewardship, perhaps reflecting different cultural settings and institutional frameworks affecting NBS implementation at the local, regional and national scales (see Nadin & Stead, 2008; Tosics, 2013). In particular, interest remains high in participative, multi-stakeholder platforms for NBS implementation and the evidence for whether these are helping to deliver integrated action on climate mitigation and adaptation. There are questions about whether co-design of NBS innovations and strategies are genuinely leveraging greater investment to deliver against these priorities.

Government agencies and knowledge brokers will be crucial for mobilising the capacity of other actors; new approaches may be required that bring multiple and novel 'agents of change' together in order to enable the development of pathways for mainstreaming NBS and ensuring Just Transitions (Bulkeley, 2020a).

Bulkeley (2020b) highlights that much of the research on the role of NBS for sustainable communities has been conducted in urban environments, with the result that we have more limited understanding of how such interventions might support the development of rural sustainability or the generation of sustainable communities at the landscape level across both urban and rural domains. Important knowledge gaps thus relate to the diverse understandings of urban c.f. rural nature; further research could therefore explore what counts as nature, what is valued and why this varies amongst individuals and communities, as well as how this can be taken into account in the development of future NBS.

11.2.3. Technically-oriented research particularly involving quantitative data

Turning to scientific research priorities involving quantitative methods, there remains a sense of urgency around the need for data on the relative performance of NBS, strongly linked with information on their cost-effectiveness as compared with conventional, 'hard' or traditional infrastructures. Specific issues raised included the need for biodiversity metrics linked with the delivery of ecosystem services, from functional or trait-based ecological perspectives (Naumann & Davis, 2020). The need for data on NBS performance is accompanied by a recognition that the cost of wide-scale monitoring programmes may be prohibitive, which was linked with potential opportunities and drawbacks associated with big-data and remote sensing approaches. Another specific element concerns whether NBS can be proven to deliver against both climate and biodiversity goals together, at different scales.

Cost-effectiveness aspects, including economic valuation knowledge gaps, are covered in more detail under (6) below, but in brief, Whiteoak (section 10) stresses that a comprehensive understanding has not yet been developed of the nature and scale of NBS benefits - and that the quantification of these benefits in monetised form would be valuable. It is important to note that the sharing and transfer of (monetisable) data on NBS benefits from H2020 projects - reportedly sought-after by investors - has not been straightforward, but remains a 'work in progress'.

Future research is required to address gaps in knowledge around how to design, implement and manage NBS to optimise biodiversity benefits. This can be pursued alongside related work to understand – pluralistically – ecosystem functioning and the delivery of co-benefits such as health and wellbeing or water management outcomes, in different settings (Naumann & Davis, 2020; Wild, 2020). Careful consideration needs to be given to the relationship with 'no-net loss' or 'net gain' strategies, particularly since there will undoubtedly be increasing pressure for landscapes to deliver carbon sequestration and other climate change–relevant services. This is closely linked with the issue of how climate change may impact on the resilience of ecosystems themselves (Calfapietra, 2020), and how decision-making is organised, supported and governed (Bulkeley, section 9 of this report).

There is also the need to better understand the direct climate mitigation benefits of NBS in terms of carbon sequestration and storage, but also indirect impacts such as the embedded carbon involved in the deployment of different types of solutions, and in a wider range of ecosystems beyond, e.g. forests (Bulkeley, 2020a). More work is also needed to quantify the decreased energy costs and reduced carbon emissions associated with NBS for mitigating urban heat island effects; understanding of these effects at the local, city and regional levels is essential to measure the contribution of NBS to the EU goal to become carbon-neutral by 2050 (Calfapietra, 2020) .

11.2.4. Policy development & associated advocacy promoting NBS implementation

Several reported priorities for R&I investment related to policy development and support for those advocating scaling-up of NBS implementation to address societal and global challenges. This included questions about how to position NBS as compared with other investment options (e.g. for climate action), how to incorporate NBS into mainstream investment programmes, and how to report progress in delivering shared international goals (e.g. SDGs) and regulatory frameworks (e.g. WFD). These representations can be linked with appeals for more stringent standards and protocols, and work to understand how best to monitor the success of these systems. Issues of scale also arose, in terms of the effectiveness of NBS beyond the local level to cover broader landscape-scale impacts, and evidence on their effectiveness, as well as tools to support their (co)design and delivery.

Biodiversity policy development represents a particular focus for NBS integration into existing systems, bearing in mind the safeguarding requirements provided for by the introductory definition of NBS. In particular, an opportunity exists for a more coordinated approach to NBS and green infrastructure deployment, enabling biodiversity protection and enhancement to be mainstreamed across a range of policies and funding instruments, and utilising enhanced spatial data on priority locations alongside capacity-building measures (Naumann & Davis, 2020). Another policy development area - linked specifically with water management and climate mitigation, but also perhaps of wider relevance – entails the need to broaden the range of perspectives inputted into EC policy-making processes. To facilitate rapid and widespread action to implement NBS measures, insights from social researchers and political sciences will be needed to complement those with technical (e.g. biological or engineering) expertise (Wild, 2020). There is a clear need to develop our understanding of the economic, social, political and cultural dimensions of designing and implementing NBS (Bulkeley, 2020a).

11.2.5. Co-production and trialling of educational programmes and initiatives

Stakeholders responding to the EC’s survey described interests in the development of educational opportunities covering both primary and higher levels. This involved teaching and awareness-raising actions, and also professional development amongst decision-makers and practitioners. A particular gap is evident as regards evidence to support educational policy and programme development in NBS together with schools. These proposals go beyond classic outdoor education, or understanding of natural environments, to include the development of students' technical know-how. Respondents highlighted the need for skills development in a wider sense, including lifelong-learning and personal development within e.g. communities facing significant socio-economic deprivation. These were linked with urgent global trends, but also with wider challenges associated with social justice and more inclusive approaches to economic restructuring and environmental quality impacts.

Furthermore, input from a wider range of academic- and non-academic experts is needed to provide research, teaching and development programmes that are more closely aligned with what might be called a knowledge-supply-chain, linking universities with industry (Wild, 2020; see also Calfapietra's (2020) 'selection programmes'). In the context of climate change and NBS, better understanding is required, covering: (a) the impact of climate change on performance characteristics of plant-, soil- and substrate- based NBS systems; (b) the local supply chain of those materials; and (c) choices as to what vegetation to plant where, considering relationships between NBS services c.f. aesthetics, c.f. biodiversity (e.g. Kabisch et al., 2016b; Fernandes & Guiomar, 2018; Hoyle et al., 2017).

A particular area of concern linked with NBS skills and professional training relates to youth unemployment (Wild, 2020), made worse by the recent economic shocks linked with COVID-19. A lack of opportunities for young people was already a systemic problem and a significant threat to cohesion in Europe prior to the pandemic, with around half of all young people in the world unemployed or underemployed and the situation likely to get worse (British Academy, 2019). In the coming years all sectors must do much more to create a wider range of chances for skills development and professional advancement. It is estimated that one billion young people will enter the labour market between 2015 and 2025, and that only 400 million of these young people will be likely to find jobs in the formal economy (World Bank, 2015). Careful consideration is required in the conception, framing and development of programmes to bring in the perspectives of young people to global sustainable development challenges. This should involve people from a wide range of backgrounds and directly include young people to shape programmes for NBS skills development using this particular lens on societal challenges.

11.2.6. Economic & financial instruments, including loans & investment funds

Reported priorities for future research and innovation in the areas of economic instruments – and the development of NBS finance programmes - varied from a sense of optimism through to deep scepticism. Stakeholders' perspectives ranged from enthusiasm around business investment as a possible solution to biodiversity loss and climate change, to distinct unease around the role of private-sector finance and the success or otherwise of previous attempts such as payments for ecosystem services. Social justice priorities (as described earlier in this section) can fall in sharp contrast with the current strong trend to promote the financialisation of ecosystems and their services, and to understand the implications of natural capital approaches. Questions about the scope for, and implications of, rolling out 'green finance' schemes were linked with the themes of just transitions and fairness, as well as issues associated with cash-flow and reluctance to take on longer-term costs of maintenance and management of NBS despite the evidence on sustained benefits e.g. savings in public health service budgets.

In short, more work appears to be needed on the relative costs and benefits of NBS in different settings, or more accurately, on who bears the costs or enjoys the benefits of these investments. Common to both of the above priorities was that stakeholders highlighted the need for evidence of the impacts of NBS in terms of transitions in rural areas, as well as in urban districts. The relative cost-effectiveness of NBS as compared with grey infrastructure remains the subject of intense debate. Indeed, there appears to be increasing disagreement, rather than convergence in opinions as to whether NBS functioning can be compared with conventional infrastructures solely in terms of the cost of delivering individual benefits, such as flood risk management. An alternative view may be that the only meaningful comparison is in how different NBS investment options provide for invaluable co-benefits, with an obvious example being catchment restoration measures that serve to deliver both flooding and WFD benefits (Vojinovic, 2020). Either way, the evidence on the values-side of cost-benefit analyses of NBS remains relatively rare, and in some cases there is also a lack of evidence on the prices-side of innovative NBS (Wild, 2017; 2019; Whiteoak, section 10 in this report).

As NBS become more frequently associated with Nationally Determined Contributions to GHG reductions (as a legitimate mitigation measure or, in the worst cases what might be considered 'greenwashing'), the links between NBS, carbon and finances are likely to become increasingly important and therefore represent a key area for future research. Climate mitigation benefits provide a basis for leveraging finance for NBS (Bulkeley, 2020a) and linked with this is the issue of where and how locations for NBS investment are targeted (Wild, 2020) as well as the ways in which NBS options are selected. Whiteoak (section 10) stresses that the rigorous use of economic analyses may reveal more NBS options than would otherwise be identified. Again, the distribution of costs and benefits, and who pays for each, remains a key consideration. Thus it is recommended that careful consideration should be given to the potential for (intended and unintended) eco-gentrification outcomes. Safeguarding against these adverse effects should be 'hard wired' into calls for proposals in these areas, e.g. in calls to produce "methodological guidance on assembling NBS business cases" (Whiteoak, section 10).

11.2.7. Development & testing of decision support systems, tools & models

Several types of decision-support systems (DSS) were stressed as being instrumental to success in widening NBS uptake, with tools for understanding the economic impacts of NBS being only one such priority. Other DSS, models and tools reportedly needed included methods to assess and understand the relative merits of NBS in terms of successful climate action (e.g. carbon savings, water management performance and heat attributes), particularly linked with maintenance regimes and performance in the light of climate change itself. Other examples included models for understanding net gain or loss of biodiversity, as well as the drivers of these changes and responses of natural systems to different protocols or regulatory systems. In some cases the importance of research and innovation to understand these characteristics in strict non-monetary terms was stressed, whereas others focussed much more heavily on economic valuation. The development of decision-support systems was also linked with issues of scale (geographical, temporal) and assessment of impacts of NBS beyond the local level.

A related area includes the performance and effectiveness of NBS at these wider scales, also linked with the issue of integration into existing networks. This applies equally to biodiversity (Naumann & Davis, 2020), water (Vojinovic, 2020; Wild, 2020), health and wellbeing (Calfapietra, 2020) and climate outcomes (Bulkeley, 2020a), but manifested in different and nuanced ways. This in itself presents a challenge for research and innovation into NBS and their co-benefits, highlighting the need for contextualised and place-specific cases. Cooperative research and innovation is required across Europe to develop new ways of understanding how multiple often individually small NBS can combine to deliver collectively significant strategies (Wild, 2020; Calfapietra, 2020), but also on large-scale individual NBS (Vojinovic, 2020), which in some locations may prove to be controversial.

Particular governance challenges requiring further attention relate to the topic of multi-scalar, multi-beneficial NBS networks and plans, and how stakeholder participation is mobilised to handle interests (Vojinovic, 2020). NBS can represent contested spaces and there is growing "acknowledgement that the presence of participatory or co-design processes should not automatically be considered as a means through which social inclusion can be fostered" (Bulkeley, 2020b).

11.3. OTHER POTENTIAL THEMES FOR FUTURE NBS RESEARCH & INNOVATION

Several other priorities have not yet been sufficiently addressed in H2020, and may prove relevant for further attention in Horizon Europe and beyond. For instance, much of the research on the role of NBS has been conducted in urban contexts, with the result that we have more limited understanding of how such interventions might support the development of rural sustainability, or the generation of sustainable communities at the landscape level across both urban and rural domains.

Research and Innovation could further explore how NBS can contribute to sustainable agriculture production systems and hence to the 'Farm to Fork' initiative. As seen in section 4, nature-based farming practices are becoming available that offer win-win scenarios, i.e. simultaneously addressing climate, biodiversity protection, soil and water management objectives. Closed-loop systems, e.g. replacing synthetic fertilsers with short supply chain systems, or re-integrating drainage systems in nature-sensitive ways, could form a focus for future projects.

Promoting NBS in rural areas could, for instance, involve a three-fold approach - broad application of agro-ecological practices; promoting agroforestry and woody landscape features; and enhancing agrobiodiversity – to deliver more resilient farming systems, healthier nutrition and human wellbeing outcomes. Large-scale NBS have strong links with agroecology, through innovative planning of agricultural landscapes with a view to increasing their multifunctionality (e.g. flood-risk management benefits, section 6). In doing so, NBS may create opportunities to support local food economies, building local businesses and creating highly skilled jobs and craftsmanship. These NBS could be implemented through systems relying on Rural Development Programmes, and in particular, agri-environmental-climate measures (CAP), or coordination across different funds.

Furthermore, in urban, rural and peri-urban areas, the Just Transition Fund has the potential to kick-start an active process for financing and governing NBS with justice explicitly embedded within its principles and practice, whilst enabling transformative action for nature. Research and innovation in these areas could for instance establish how to prioritise 'green' over 'grey' solutions, providing a route to support vulnerable communities and regions to cope with transformative change through investments in NBS in old-industrial, low-income or disaster-hit areas. Examples could include regenerating urban catchments and heavily modified waterbodies (section 5), or ameliorating air quality and heat island issues using urban or peri-urban mini-forests and green corridors in the form of riverside parkways.

Finally, from a strategic perspective, the generation of programme-level data on NBS communities of practice remains underdeveloped. Further investment in this NBS knowledge economy and the 'harvesting' of cooperation potentials is justified to underpin emerging professional development and international trade based on European NBS expertise. An important gap needing addressed involves synthesising and enhancing knowledge around participation of different sectors in events, training and continual professional development activity, as imitated by H2020 and other NBS projects. Better understanding of these processes would support improved capacity-building action, by developing knowledge exchange and accelerating impacts across clusters of projects and programmes.

These new themes constitute promising opportunities and, together with the other topics explored in this report, reinforce the need for further investment in NBS Research and Innovation. As we transition into Horizon Europe, and in the context of the development of the European Green Deal, NBS emerge as a solid opportunity to address urgent societal challenges including climate change and biodiversity loss, which have both reached crisis status. The EC will continue to work on Research and Innovation for NBS by developing the knowledge base, strengthening the NBS community of practice, advancing the development, uptake and upscaling of innovative NBS, and mainstreaming NBS in EU policies and at the international level, thus consolidating the EU as the global leader in innovating with nature.

REFERENCES

Abbott, C. & Comino-Mateos, L. (2003). In-situ hydraulic performance of a permeable pavement sustainable urban drainage system. Water and Environment Journal, 17: 187–190.

Abhijit, K.V. et al. (2017). Air pollution abatement performances of green infrastructure in open road and built-up street canyon environments - A review. Atmospheric Environment, 162: 71-86

Acero, J.A. & Herranz-Pascual K. (2015). A comparison of thermal comfort conditions in four urban spaces by means of measurements and modelling techniques. Building and Environment, 93(2): 245.

Acreman, M. & Holden, J. (2013). How wetlands affect floods. Wetlands, 33: 773-786.

Akbari, H. (2002). Shade trees reduce building energy use and CO_2 emissions from power plants. Environmental Pollution, 116: 119-126.

Albert, C. et al. (2019). Addressing societal challenges through nature-based solutions: How can landscape planning and governance research contribute? Landscape and Urban Planning, 182: 12-21.

Alfredo K., Montalto F. & Goldstein A. (2010). Observed and modelled performances of prototype green roof test plots subjected to simulated low- and high-intensity precipitations in a laboratory experiment. Journal of Hydrologic Engineering, 15 (6): 444-457.

Allen, J. (2004). The whereabouts of power: politics, government and space. Geografiska Annaler, 86 B (1): 19-32.

Almassy, D. et al. (2018). Urban Nature Atlas: A Database of Nature-Based Solutions Across 100 European Cities, https://naturvation.eu/result/results-urban-nature-atlas (accessed March 2020).

Altamirano M.A. & de Rijke H. (2017). Costs of infrastructures: elements of method for their estimation, EU H2020 NAIAD Project, Deliverable 4.2, Final Version. https://cordis.europa.eu/project/id/730497/results (accessed March 2020).

Alterra (2012). Mitigation options for nutrient reduction in surface water and groundwaters. European Cost Action 869: www.cost869.alterra.nl.

Alves, A. et al. (2019). Assessing the co-benefits of green-blue-grey infrastructure for sustainable urban flood risk management. Journal of Environmental Management, 239: 244–254. DOI: 10.1016/j.jenvman.2019.03.036.

Amann, M. et al (2012). TSAP-2012 Baseline: Health and Environmental Impacts TSAP Report #6. EC DG-ENV Service Contract on Monitoring and Assessment of Sectorial Implementation Actions (ENV.C.3/SER/2011/0009).

Ambrose-Oji, B. et al. (2017). Innovative Governance for Urban Green Infrastructure: A Guide for Practitioners. GREEN SURGE Project Deliverable 6.3. Copenhagen, University of Copenhagen.

Amoly, E. et al. (2014). Green and blue spaces and behavioral development in Barcelona schoolchildren: the Breathe project. Environmental Health Perspectives 122(12): 1351-1358.

Anguelovski, I. et al. (2018). Green Trajectories: municipal policy trends and strategies for greening in Europe, Canada and United States (1990-2016), GreenLULUs Project. https://ddd.uab.cat/record/201044

Anguelovski, I. et al. (2019). New scholarly pathways on green gentrification: What does the urban 'green turn' mean and where is it going? Progress in Human Geography, 43(6): 1064–1086.

Anguelovski, I., Connolly, J. & Brand, A. L. (2018). From landscapes of utopia to the margins of the green urban life: for whom is the new green city? City, 22(3): 417-436.

Apostolaki, S., Jefferies, C. & Wild, T. (2005). The social impacts of stormwater management techniques. 10th international conference of urban drainage, Copenhagen, Denmark.

AQUACROSS (2016). Managing aquatic biodiversity: from local to global – an EU perspective. https://aquacross.eu/sites/default/files/AQUACROSS_brief.pdf

Aram, F. et al. (2019). Urban green space cooling effect in cities. Heliyon, 5(4): e01339.

ARTS (2016). The Natural Nexus: How Nature-Based Solutions Can Help Restore the Planet and Civil Society. Transition Read N°2 http://acceleratingtransitions.eu/wp/?wpdmdl=1501

Ashley, R. (2015). Synchronicity: Multiple Benefits from Green Infrastructure (Looking at SUDS from both sides now). Green Infrastructure: a growing need. 6th & 7th October 2015. Scottish Green Infrastructure Forum, Glasgow.

Ashley, R. et al. (2011). A Review of Current Knowledge Surface Water Management and Urban Green Infrastructure A review of potential benefits and UK and international practices. FR/R0014. Foundation for Water Research, Marlow, England.

Aspinall, P. et al. (2015). The urban brain: Analysing outdoor physical activity with mobile EEG. British Journal of Sports Medicine, 49: 272-276.

Autuori, S. et al. (2019). EU H2020 PHUSICOS Project Deliverable 4.1, Comprehensive Framework for NBS Assessment, Final Version. https://phusicos.eu/wp-content/uploads/2019/05/D4.1_Task4.1_UNINA_14052019_Final_withAppendicies.pdf (accessed March 2020).

Balke, T. et al. (2011). Windows of opportunity: thresholds to mangrove seedling establishment on tidal flats. Marine Ecology Progress Series, 440: 1–9.

Balzan, M.V. (2017). Ecology for the city: analysing the role of green infrastructure in creating liveable cities. Valletta 2018 European Culture of Capital Conference: Living Cities, Liveable Spaces: Placemaking & Identity.

Baró, F. et al. (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.

Baró, F. et al. (2015). Mismatches between ecosystem services supply and demand in urban areas: A quantitative assessment in five European cities. Ecological Indicators, 55: 146-158.

Baroni, L., Nicholls, G. & Whiteoak, K. (2019) Approaches to financing nature-based solutions in cities. GrowGreen Project working document. http://growgreenproject.eu/wp-content/uploads/2019/03/Working-Document_Financing-NBS-in-cities.pdf

Barton, D.N. (2015). Monetary valuation of urban ecosystem services-operationalization or tragedy of well-intentioned valuation? An illustrated example. Ecosystem Services: concepts, methodologies and instruments for research and applied use, 65.

Barton, D.N. et al. (2017). Integrated assessment and valuation of ecosystem services. OpenNESS Project Deliverable 3.3/4.4. http://www.openness-project.eu/sites/default/files/OpenNESS%20D33-44_Integrated_assessment%26valuation_of_ES_FINAL2.pdf (accessed 20 April 2020).

Bastin, J.F. et al. (2019). The global tree restoration potential. Science; 365 (6448): 76-79.

Bayertz, K. (1999). Four uses of “solidarity”. pp 3-28. In: K. Bayertz (Ed.) Solidarity. Dordrecht, Kluwer. http://dx.doi.org/10.1007/978-94-015-9245-1_1

Bayraktarov, E. et al. (2016). The cost and feasibility of marine coastal restoration. Ecological Applications, 26: 1055-1074.

Bazaz, A. et al. (2018). Summary for Urban Policy Makers: what the IPCC Special Report on Global Warming of 1.5 degrees means for cities, IPCC. https://www.c40.org/researches/summary-for-urban-policymakers-what-the-ipcc-special-report-on-global-warming-of-1-5-c-means-for-cities (accessed March 2020).

Bekkby, T. (2017). State of the knowledge on European marine habitat mapping and degraded habitats. MERCES project Deliverable 1.1.

Bellamy, J. & Osaka, S. (2020). Unnatural climate solutions? Nature Climate Change, 10: 98-99.

BenDor, T. et al. (2015). Estimating the size and impact of the ecological restoration economy. PloS one, 10(6): e0128339. doi: 10.1371/journal.pone.0128339.

Bengtsson L., Grahn L. & Olsson, J. (2005). Hydrological function of a thin extensive green roof in southern Sweden. Nordic Hydrology, 36 (3): 259-268.

Berg, H. et al. (2016). Report on PAR Analysis. PATHWAYS Project Deliverable D3.2. https://www.pathways-project.nl/sites/default/files/Pathways_D32_layout_final.pdf (accessed March 2020).

Berndtsson, J.C. (2010). Green roof performance towards management of runoff water quantity and quality: A review. Ecological Engineering 36(4): 351-360.

Bernhardt, E.S. et al. (2005). Synthesizing U.S. river restoration efforts. Science, 308(5722): 636-637.

Berry, P. (2018). Nature-based Solutions for sustainable and resilient cities. A review of FP7 projects. Internal DG RTD report, Brussels, European Commission.

BESAFE (2015). Final publishable summary (1 September 2011 – 31 August 2015). https://cordis.europa.eu/project/id/282743/reporting (accessed 10/02/2020)

Besir, A. & Cuce, E. (2018). Green roofs and facades: A comprehensive review. Renewable and Sustainable Energy Reviews, 82: 915–939.

Biodiversa (undated).

BIOMOT (2015). Final Report Summary - BIOMOT (MOTivational strength of ecosystem services and alternative ways to express the value of BIOdiversity). https://cordis.europa.eu/project/id/282625/reporting (accessed 08/02/2020).

Bizzi, S. et al. (2016). The use of remote sensing to characterise hydromorphological properties of European rivers. Aquatic Sciences, 78(1): 57-70.

Bledsoe, B.P. et al. (2016). Stream restoration as a BMP. Report prepared for the Water Environment & Reuse Foundation (WE&RF), Alexandria, Vancouver.

Bockarjova, M. & Botzen, W.J.W. (2017). Review of Economic Valuation of Nature-Based Solutions in Urban Areas. Naturvation Project Deliverable 1.3 Part III. https://naturvation.eu/sites/default/files/result/files/naturvation_review_of_economic_valuation_of_nature_based_solutions_in_urban_areas.pdf

Bonn, A. et al. (Eds.) (2016). Peatland restoration and ecosystem services: science, policy and practice. Cambridge, Cambridge University Press.

Borja, A. & Elliott, M. (2007). What does 'good ecological potential' mean, within the European Water Framework Directive? Marine Pollution Bulletin 54(10): 1559-1564.

Borja, A. et al. (2013). Transitional and coastal waters ecological status assessment: Advances and challenges resulting from implementing the European Water Framework Directive. Hydrobiologia, 704(1): 213-229.

Borysiak, J. et al. (2016). Floral biodiversity of allotment gardens and its contribution to urban green infrastructure. Urban Ecosystems, 20: 323–335.

Branquinho, C., Matos, P. & Pinho, P. (2015). Lichens as ecological indicators to track atmospheric changes: future challenges. In: D.B. Lindenmeyer, J. Pierson & P. Barton (Eds.) Surrogates and indicators in ecology, conservation and environmental management. CSIRO Publishing, London.

British Academy (2019). https://www.thebritishacademy.ac.uk/programmes/youth-futures (accessed 26 November 2019).

Britton, E. et al. (2020). Blue care: a systematic review of blue space interventions for health and wellbeing. Health Promotion International, 35: 50-69.

Broadhead, A.T., Horn, R. & Lerner, D.N. (2013). Captured streams and springs in combined sewers: A review of the evidence, consequences and opportunities. Water Research, 47(13): 4752-4766.

Brown, R.R., Farrelly, M.A. & Loorbach, D.A. (2013). Actors working the institutions in sustainability transitions: The case of Melbourne's stormwater management. Global Environmental Change, 23(4): 701-718.

Buijs, A. et al. (2019). Mosaic governance for urban green infrastructure: Upscaling active citizenship from a local government perspective, Urban Forestry and Urban Greening, 40: 53–62.

Bulkeley, H & Betsill, M.M. (2013). Revisiting the Urban Politics of Climate Change. Environmental Politics, 22(1): 136–54.

Bulkeley, H. (2015). Accomplishing Climate Governance. Cambridge University Press.

Bulkeley, H. (2017). State of the Art Review: Overview. Naturvation project Deliverable 1.3. Durham University.

Bulkeley, H. (2019). Taking Action for Urban Nature: Growing Effective Governance Solutions, Naturvation Deliverable 4.5. https://naturvation.eu/result/taking-action-urban-nature-governance-solutions (accessed March 2020).

Bulkeley, H. (2020a). Nature-based Solutions for climate mitigation: analysis of EU-funded projects. EU Publications Office, Luxembourg.

Bulkeley, H. (2020b). Nature-based Solutions: towards sustainable communities - analysis of EU-funded projects. EU Publications Office, Luxembourg.

Bulkeley, H. & Kern, K. (2006). Local government and climate change governance in the UK and Germany. Urban Studies, 43 (12): 2237-2259.

Bullock, A. & Acreman, M. (2003). The Role of Wetlands in the Hydrological Cycle. Hydrology & Earth System Sciences, 7(3): 358-389. doi:10.5194/hess-7-358-2003.

Burke, S. et al. (2018). Lower Danube (Romania). In: P. Van der Keur et al. (Eds.): From hazard to risk: models for the Demonstrators. H2020 NAIAD Project Deliverable D6.2.

Burke, S. et al. (2020). Innovating to understand investments in nature-based solutions for flood mitigation from the point to the Danube scale. https://platform.think-nature.eu/system/files/s8_swinkels.pdf (accessed 12 March 2020).

Burszta-Adamiak, E. & Mrowiec, M. (2013). Modelling of Green roofs' hydrologic performance using EPA's SWMM. Water Science and Technology, 68: 36–42. doi:10.2166/wst.2013.219.

CABE, (2011). Cheonggyecheon Restoration Project. London, Commission for Architecture and the Built Environment. Available online: https://webarchive.nationalarchives.gov.uk/20110118101111/http://www.cabe.org.uk/case-studies/cheonggyecheon-restoration-project (accessed March 2020).

Calatrava, J. et al. (2018). Economic water-related risk damage estimation. NAIAD Project Deliverable 4.3.

Calfapietra, C. (2020). Nature-based Solutions for microclimate regulation and air quality: analysis of EU-funded projects. EU Publications Office, Luxembourg.

Calfapietra, C. et al. (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. et al. (2016). Uptake of O3 by urban and peri-urban forests: evidences from laboratory, field and modelling approaches. Journal of Environmental Quality, 45: 224-233.

Calfapietra, C., Peñuelas, J. & Niinemets, Ü. (2015). Urban Plant Physiology: adaptation-mitigation strategies under permanent stress. Trends in Plant Science, 20: 72-75.

Campbell, N. et al. (2005). Diffuse Pollution: An Introduction to the Problems and Solutions. IWA Publishing, London.

Cariñanos, P. et al. (2015). Characterization of allergen emission sources in urban areas. Journal of Environmental Quality, 45: 244-252.

Carpenter, D.D. & Kaluvakolanu, P. (2011). Effect of Roof Surface Type on Storm-Water Runoff from Full-Scale Roofs in a Temperate Climate. Journal of Irrigation and Drainage Engineering, 137: 161–169. doi:10.1061/(ASCE)IR.1943-4774.0000185.

Carrus, G. et al. (2015). Go greener, feel better? The positive effects of biodiversity on the well-being of individuals visiting urban and peri-urban green areas. Landscape and Urban Planning, 13: 221-228.

Carvalho, L. et al. (2019). Protecting and restoring Europe's waters: An analysis of the future development needs of the Water Framework Directive. Science of The Total Environment, 658: 1228-1238.

CBD (2019). Including food systems, biodiversity, nutrition and health in the post-2020 global biodiversity framework. CBD/SBSTTA/23/INF/11. Montreal, Convention on Biological Diversity.

Center for Neighborhood Technology (2010). The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental and Social Benefits. Available at: http://www.cnt.org/sites/default/files/publications/CNT_Value-of-Green-Infrastructure.pdf (accessed 8 April 2020).

Center for New York City Law (2019). New York City Green Roof Laws Take Effect. https://www.citylandnyc.org/29502-2/ (accessed 20 April 2020).

Chan, F.K.S. et al. (2018). "Sponge City" in China: A breakthrough of planning and flood risk management in the urban context. Land Use Policy, 76: 772-778. doi: 10.1016/j.landusepol.2018.03.005.

Chapman, C. & Horner, R.R. (2010). Performance assessment of a street-drainage bioretention system. Water Environment Research, 82 (2): 109-119.

Chapman, E. et al. (2018). Developing the RESIN tools, advancing local adaptation recommendations for co-creation in applied research. RESIN Project Deliverable 4.2.

Chou R.J. (2016). Achieving Successful River Restoration in Dense Urban Areas: Lessons from Taiwan. Sustainability, 8(11): 1159. https://doi.org/10.3390/su8111159.

CIRCABC (2017). Common Implementation Strategy for the Water Framework Directive and the Floods Directive: Natural Conditions in relation to WFD Exemptions. EU Water Directors, Tallinn, December 2017.

CIRCABC (2018). Common Implementation Strategy for the Water Framework Directive and the Floods Directive: Work Programme 2019-2021. EU Water Directors, Vienna, November 2018.

CIRIA (2000). Sustainable urban drainage systems - design manual for Scotland and Northern Ireland. CIRIA Report C521. Construction Industry Research and Information Association, Dundee.

CIRIA (2001). Sustainable urban drainage systems - best practice manual for England, Scotland, Wales and Northern Ireland. CIRIA Report CR086A. Construction Industry Research and Information Association, London.

CIRIA (2007; 2015). The SUDS manual. C697. London, Construction Industry Research and Information Association (2007 edition; 2015 updated version).

CIRIA (2015). Guidance on the construction of SuDS (C768). London, CIRIA.

CIS (2016). WFD Reporting Guidance 2016 Final – Version 6.0.6. Common Implementation Strategy for the Water Framework Directive and the Floods Directive. EU Water Directors Meeting, Heraklion.

Clary, J. et al. (2017a). International Stormwater BMP Database 2016 summary statistics. Water Environment & Reuse Foundation. Alexandria, Virginia.

Clary, J. et al. (2017b). Agricultural BMP Database Project Summary 2017. Water Environment & Reuse Foundation. Alexandria, Virginia.

Collier, M. (2016). Final project report: TURas (Transitioning towards Urban Resilience and Sustainability). https://cordis.europa.eu/docs/results/282/282834/final1-turas-final-report.pdf

Connecting Nature (2019). Engaging the Un-Usual Suspects. https://connectingnature.eu/engaging-un-usual-suspects (accessed March 2020).

Connecting Nature (2020). Financing and Business Models. https://connectingnature.eu/financing-and-business-models (accessed 20 April 2020).

Connop, S. et al. (2011). Barking Riverside: Office landscaping for biodiversity. Essex Naturalist, 28: 49-67.

Connop, S. et al. (2016). Renaturing cities using a regionally-focused biodiversity-led multifunctional benefits approach to urban green infrastructure. Environmental Science and Policy, 62: 99-111.

Conrad, E. et al. (2011). Rhetoric and Reporting of Public Participation in Landscape Policy, Journal of Environmental Policy & Planning, 13(1): 23-47.

Cooper, C. (2017). Establishing links to relevant databases of social, economic and health indicators. NATURVATION Project Milestone 2.2.

Cuttle, S.P. et al. (2007). An inventory of methods to control diffuse water pollution from agriculture. DEFRA- Project ES0303.

D'Arcy, B.J. et al. (2000). Diffuse pollution impacts: the environmental and economic impacts of diffuse pollution in the UK. Terence Dalton Publishers, Lavenham, Suffolk, UK. ISBN 1870752465.

da Rocha, S. M., Almassy, D. & Pinter, L. (2017). Social and cultural values and impacts of NBSs and natural areas. NATURVATION Project Deliverable 1.3 Part IV.

Dadvand, P. et al. (2015). Green spaces and cognitive development in primary schoolchildren. Proceedings of the National Academy of Sciences, 112 (26): 7937-7942.

Dadvand, P. et al. (2019). Green spaces and child health and development. In: M.R. Marselle et al. (Eds.) Biodiversity and Health in the Face of Climate Change, pp. 121-132. Springer.

Damodaram, C. et al. (2010). Simulation of combined best management practices and low impact development for sustainable stormwater management. Journal of the American Water Resources Association, 46: 907–918. doi:10.1111/j.1752-1688.2010.00462.x.

Davis, A.P. et al. (2001). Laboratory study of biological retention for urban stormwater management. Water Environment Research, 73(1): 5–14.

Davis, M. & Naumann, S. (2017). Making the case for sustainable urban drainage systems as a nature-based solution to urban flooding. In: N.Kabisch et al. (Eds.) Nature-Based Solutions to Climate Change Adaptation in Urban Areas (pp 123-137). Springer, Cham.

Davis, M. et al. (2018). Nature-based solutions in European and national policy frameworks. NATURVATION Project Deliverable 1.5.

Debele, S.E. et al. (2019). Nature-based solutions for hydro-meteorological hazards: Revised concepts, classification schemes and databases. Environmental Research, 179: 108799. doi:10.1016/j.envres.2019.108799

de Jong M. et al. (2018). Standardization in urban climate adaptation, EU H2020 RESIN, Deliverable 5.1/2.2. https://resin-cities.eu/fileadmin/user_upload/Papers/RESIN-D5.1_Standardization_in_urban_climate_adaptation_NEN_30102018.pdf (accessed March 2020)

de Keijzer, C. et al. (2017). The association of air pollution and greenness with mortality and life expectancy in Spain: A small-area study. Environment International, 99: 170-176.

de Leeuw J.J. et al. (2007). Challenges in developing fish-based ecological assessment methods for large floodplain rivers. Fisheries Management & Ecology 14(6): 483-494.

de Vriend, H. J. et al. (2015). Sustainable hydraulic engineering through Building with Nature. Journal of Hydro-environment Research, 9: 159-171.

de Vries, S. et al. (2003). Natural environments—healthy environments? An exploratory analysis of the relationship between greenspace and health. Environment and Planning A, 35(10): 1717-1731.

Defra (2013). Catchment Based Approach: Improving the quality of our water environment https://www.gov.uk/government/publications/catchment-based-approach-improving-the-quality-of-our-water-environment (accessed 21 February 2020).

Dempsey, N. & Burton, M. (2011). Defining place-keeping: The long-term management of public spaces. Urban Forestry and Urban Greening, 11: 11– 20.

Dhakal, K.P. & Chevalier, L.R. (2017). Managing urban stormwater for urban sustainability: Barriers and policy solutions for green infrastructure application. Journal of Environmental Management 203: 171–181. DOI: 10.1016/j.jenvman.2017.07.065.

DHI (2017). Quantified ESS for 3 mature sites including recommendations for application. DESSIN Project Deliverable 13.1. https://dessin-project.eu/?wpdmpro=quantified-ess-for-3-mature-sites-including-recommendations-for-application-d13-1.

Diaz, S. et al. (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services – unedited advance version, IPBES. https://www.ipbes.net/news/ipbes-global-assessment-summary-policymakers-pdf (accessed March 2020).

Dietz, M.E. (2007). Low impact development practices: A review of current research and recommendations for future directions. Water, Air and Soil Pollution, 186(1-4): 351-363. DOI:10.1007/s11270-007-9484-z.

Dixon, S.J. et al. (2016) The effects of river restoration on catchment scale flood risk and flood hydrology. Earth Surface Processes and Landforms, 41: 997 - 1008.

Domisch, S. et al. (2017). Modelling approaches for the assessment of projected impacts of drivers of change on biodiversity, ecosystems functions and aquatic ecosystems service delivery. AQUACROSS project deliverable D7.1.

Dong, X., Guo, H. & Zeng, S. (2017). Enhancing future resilience in urban drainage system: Green versus grey infrastructure, Water Resources, 124: 280–289. https://doi.org/10.1016/j.watres.2017.07.038, 2017

Donovan, G.H. & Butry, D.T. (2010). Trees in the city: Valuing street trees in Portland, Oregon. Landscape and Urban Planning. 94(2): 77-83.

EASME (2020). Examples of LIFE projects that have increased biodiversity on intensively used farmland. EASME Request – DENTE HUB Agriculture – April 2020.

EC (2012). A Blueprint to Safeguard Europe's Water Resources. COM/2012/0673, https://ec.europa.eu/environment/water/blueprint/index_en.htm (Accessed April 2020). Brussels, European Commission.

EC (2013). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions 'An EU Strategy on adaptation to climate change' (COM(2013) 216 final). Brussels, European Commission.

EC (2015a). Towards an EU research and innovation policy agenda for nature-based solutions & re-naturing cities. Final report of the Horizon 2020 expert group on 'Nature-based solutions and re-naturing cities'. European Commission, Brussels.

EC (2015b). The fourth implementation report: Assessment of the Water Framework Directive Programmes of Measures and the Flood Directive, Communication and Staff Working Documents (http://ec.europa.eu/environment/water/water-framework/impl_reports.htm#fourth).

EC (2016). European Commission staff working document – Action Plan on the Sendai Framework for Disaster Risk Reduction 2015-2030, A disaster risk-informed approach for all EU policies. Brussels, 16.6.2016 SWD(2016) 205 final/2. https://ec.europa.eu/echo/sites/echo-site/files/sendai_swd_2016_205_0.pdf (accessed May 2020).

EC (2019a). European Overview - River Basin Management Plans: accompanying the document implementation of the Water Framework Directive and the Floods Directive (Report from EC to European Parliament and Council). SWD(2019)30 final. European Commission, Brussels.

EC (2019b). Fitness Check of the Water Framework Directive, Groundwater Directive, Environmental Quality Standards Directive and Floods Directive. SWD(2019)439 final. European Commission, Brussels.

EC (2019c). Report from the EC to the EU Parliament and the Council on the implementation of the Water Framework Directive (2000/60/EC) and the Floods Directive (2007/60/EC): 2nd River Basin Management Plans; 1st Flood Risk Management Plans. COM(2019) 95 final. European Commission, Brussels.

EC (2019d). Evaluation of the Urban Waste Water Treatment Directive. SWD(2019)700 final. European Commission, Brussels.

EC (2019e). Annex to COM(2019)640: The European Green Deal. Brussels, European Commission. https://ec.europa.eu/info/sites/info/files/european-green-deal-communication-annex-roadmap_en.pdf (accessed 20 April 2020).

EC (2019f). Air Quality Standards. https://ec.europa.eu/environment/air/quality/standards.htm. Updated 31/12/2019 (accessed April 2020).

EC (2020). Heating and cooling. https://ec.europa.eu/energy/topics/energy-efficiency/heating-and-cooling_en. Published July 2015, updated 23 April 2020.

Eckart, K., McPhee, Z. & Bolisetti,T. (2017). Performance and implementation of low impact development - A review. Science of the Total Environment, 607: 413-432.

ECONADAPT (2015). The Costs and Benefits of Adaptation: Results from the ECONADAPT Project. P. Watkiss (Ed.). https://econadapt.eu/sites/default/files/docs/Econadapt-policy-report-on-costs-and-benefits-of-adaptaiton-july-draft-2015.pdf (accessed May 2020).

EEA (2017). What is Green Infrastructure? Copenhagen, European Environment Agency. https://www.eea.europa.eu/themes/sustainability-transitions/urban-environment/urban-green-infrastructure/what-is-green-infrastructure (accessed 20 April 2020).

EEA (2018). European Waters – Assessment of status and pressures 2018, EEA Report No 7/2018, ISSN-1977-8449. European Environment Agency, Copenhagen.

EEA (2019). Exceedance of air quality standards in urban areas. https://www.eea.europa.eu/data-and-maps/indicators/exceedance-of-air-quality-limit-3/assessment-5. Published July 2019 (accessed April 2020).

EEA (forthcoming). State of Nature in the EU report. Copenhagen, European Environment Agency.

EFH (2019). The implementation of the EU 2020 Biodiversity Strategy and recommendations for the post 2020 Biodiversity Strategy. European Habitats Forum. https://www.europarc.org/wp-content/uploads/2019/05/EHF-paper_Post-2020-EU-Biodiversity-Strategy_May2019 (accessed April 2020).

Eggermont, H. et al. (2015). Nature-Based Solutions: New influence for environmental management and research in Europe. Gaia, 24(4): 243-248.

Egusquiza, A. et al. (2017). NBS Implementation Models Typology. Nature4Cities Deliverable 1.2. https://www.nature4cities.eu/post/nature4cities-typology-nature-based-solutions-implementation-models (accessed April 2020).

Eisenman, T.S. et al. (2019). Urban trees, air quality, and asthma: An interdisciplinary review. Landscape and Urban Planning, 187: 47-59.

EKLIPSE (undated). Health activities. http://www.eklipse-mechanism.eu/health_activities (accessed April 2020).

Elands, B. et al. (2019). Biocultural diversity: A novel concept to assess human-nature interrelations, nature conservation and stewardship in cities. Urban Forestry and Urban Greening, 40: 29-34.

Eleftheriadou, E., Giannopoulou, I. & Yannopoulos, S. (2015). The European Flood Directive: Current implementation and technical issues in transboundary catchments, Evros/Maritsa example. European Water, 52: 13–22.

Eliasson, I. & Upmanis, H. (2000). Nocturnal airflow from urban parks - implications for city ventilation. Theoretical and Applied Climatology, 66: 95-107.

Ellis, J.B. & Mitchell, G. (2006). Urban diffuse pollution: key data information approaches for the Water Framework Directive. Water and Environment Journal, 20(1): 19-26.

Elmqvist, T. et al. (2016). Benefits of restoring ecosystem services in urban areas. Current Opinion in Environmental Sustainability, 14: 101-108.

ELN-FAB (2012). Functional agrobiodiversity: Nature serving Europe's farmers. Tilburg, the Netherlands: ECNC-European Centre for Nature Conservation.

Engstrom, R. et al. (2018). Multi-functionality of nature-based and other urban sustainability solutions: New York City study. Land Degradation and Development, 29: 3653 - 3662.

Ercolani, G. et al. (2018). Evaluating performances of green roofs for stormwater runoff mitigation in a high flood risk urban catchment. Journal of Hydrology, 566: 830–845. doi:10.1016/j.jhydrol.2018.09.050.

Estreguil, C. et al. (2019). Strategic green infrastructure and ecosystem restoration: geospatial methods, data and tools, EUR 29449 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-79-97294-2, doi:10.2760/06072, JRC113815.

EU (2007). Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks. Brussels, European Parliament.

EU (2020). What is the Urban Agenda for the EU? https://ec.europa.eu/futurium/en/urban-agenda-eu/what-urban-agenda-eu (accessed March 2020).

Everett, G., Lawson, E. & Lamond, J. (2015). Green infrastructure and urban water management. In: D.Sinnett et al. (Eds.) Handbook on Green Infrastructure: 50-66. Edward Elgar Publishing.

Fairburn, J. & Smith, G. (2009). Environmental justice in South Yorkshire: locating social deprivation and poor environments using multiple indicators. Local Environment, 14: 139-54.

Fairburn, J., Walker, G. & Smith, G. (2005). Investigating Environmental Justice in Scotland - Links Between Measures of Environmental Quality and Social Deprivation. Report UE4(03)01. Edinburgh, SNIFFER.

Faivre, N. et al. (2017). Nature-Based Solutions in the EU: Innovating with nature to address social, economic and environmental challenges. Environmental Research, 159: 509–518. doi:10.1016/j.envres.2017.08.032.

Faivre, N. et al. (2018). Translating the Sendai Framework into action: The EU approach to ecosystem-based disaster risk reduction. International Journal of Disaster Risk Reduction, 32: 4–10. doi:10.1016/j.ijdrr.2017.12.015.

Farinha-Marques, P. & Lameiras, J.L. (2017). Eastern and West-Central Asprela Parks, Porto, Portugal: a new green infrastructure to mitigate climate change in the urban context. CITTA 10th Annual Conference on Planning Research. Planning for Climate Change: Political Climate and Policy Changes. 12th May 2017 AESOP, Porto.

Fassman, E.A. (2010). Urban runoff mitigation by a permeable pavement system over impermeable soils. Journal of Hydrologic Engineering, 15: 475–485.

Ferguson, B.C., Frantzeskaki, N. & Brown, R.R. (2013). A strategic program for transitioning to a Water Sensitive City. Landscape and Urban Planning, 117: 32-45.

Fernandes, J.P. & Guiomar, N. (2018). Nature-based solutions: The need to increase the knowledge on their potentialities and limits. Land Degradation and Development 29(6): 1925-1939.

Ferrario, F. et al. (2014). The effectiveness of coral reefs for coastal hazard risk reduction and adaptation. Nature Communications. doi:10.1038/ncomms4794.

Filazzola, A., Shrestha, N. & MacIvor, J.S. (2019). The contribution of constructed green infrastructure to urban biodiversity: A synthesis and meta-analysis. Journal of Applied Ecology 56(9): 2131-2143.

Fletcher, T.D., et al. (2015). SUDS, LID, BMPs, WSUD and more – The evolution and application of terminology surrounding urban drainage. Urban Water Journal, 12(7): 525-542.

Fohlmeister, S. et al. (2019). Starter Toolbox for Stakeholder Knowledge Mapping to Co-Design NBS at Case Study Sites. PHUSICOS Project Deliverable D3.2. https://phusicos.eu/wp-content/uploads/2019/04/PHUSICOS_D3_2r_WP3_final_20190331.pdf (accessed March 2020).

Forestry Commission (2016). Our vision for a resilient urban forest. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/700389/urban-forest-final-v4.pdf

Lafortezza, R. (forthcoming). Roadmap for implementation of nature-based solutions in public policy: legislation, stakeholders and context analysis. Manuscript in preparation.

Frantzeskaki, N. (2019). Seven lessons for planning nature-based solutions in cities. Environmental Science and Policy, 93: 101–111.

Fuhr, H., Hickmann, T. & Kern, K. (2018). The role of cities in multi-level climate governance: local climate policies and the 1.5 C target. Current Opinion in Environmental Sustainability, 30: 1–6.

Gafni, A. (2006). Economic evaluation of health-care programmes: is CEA better than CBA? Environmental and Resource Economics 34(3):407–418.

Garfí, M., Flores, F. & Ferrer, I. (2017). Life cycle assessment of wastewater treatment systems for small communities: activated sludge, constructed wetlands and high rate algal ponds. Journal of Cleaner Production, 16: 211-219.

Gartland, L. (2012). Heat Islands: Understanding and Mitigating Heat in Urban Areas, p208. London, Earthscan Ltd.

Gascon, M. et al. (2016). Residential green spaces and mortality: A systematic review. Environment International, 86: 60-67.

Gascon, M. et al. (2017). Outdoor blue spaces, human health and well-being: A systematic review of quantitative studies. International Journal of Hygiene and Environmental Health, 4: 1207-1221.

Gellinck, L. (2013). VALUE: Valuing Attractive Landscapes in Urban Economy (project summary). In: 2013: een Plattelandsodyssee – 25 jaar VLM. https://www.vlm.be/nl/SiteCollectionDocuments/Forms/AllItems.aspx (accessed 12 March 2020).

George, G. & Bock, A. J. (2011). The business model in practice and its Implications for entrepreneurship research. Entrepreneurship Theory and Practice, 35(1): 83–111. doi: 10.2139/ssrn.1490251.

Gerner, N.V. et al. (2018). Large-scale river restoration pays off: A case study of ecosystem service valuation for the Emscher restoration generation project. Ecosystem Services, 30: 327-338.

Gill, S.E. et al. (2007). Adapting cities for climate change: the role of the green infrastructure. Built Environment, 33: 115-133.

Giordano, R. et al. (2019). Deployment of the community-based monitoring system and implementation of the platform. NAIAD Project Deliverable 3.4. http://naiad2020.eu/wp-content/uploads/2019/06/D3.4_FINAL.pdf (accessed March 2020).

Glenk, K. et al. (2018). The economics of peatland restoration. Journal of Environmental Economics and Policy, 7(4): 345-362.

Gómez-Baggethun, E., & Barton, D. N. (2013). Classifying and valuing ecosystem services for urban planning. Ecological Economics, 86: 235-245.

Goncalves, M.L.R. et al. (2018). Modelling the effects of introducing low Impact development in a tropical city: a case study from Joinville, Brazil. Sustainability, 10: 728. doi:10.3390/su10030728.

Goniewicz K. & Burkle F.M. (2019). Challenges in implementing Sendai framework for disaster risk reduction in Poland. International Journal of Environmental Research and Public Health, 16(14): 2574; https://doi.org/10.3390/ijerph16142574.

Gorissen, L. et al. (2018). Moving towards systemic change? Investigating acceleration dynamics of urban sustainability transitions in the Belgian City of Genk. Journal of Cleaner Production, 173: 171-185.

Gorito, A.M. et al. (2017). A review on the application of constructed wetlands for the removal of priority substances and contaminants of emerging concern listed in recently launched EU legislation. Environmental Pollution, 227: 428-443.

Graveline, N. et al. (2017). General framework for the economic assessment of Nature Based Solutions and their insurance value. NAIAD Project Deliverable 4.1. https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5b885d228&appId=PPGMS

Green, S.M. et al. (2018). Methane and carbon dioxide fluxes from open and blocked ditches in a blanket bog. Plant Soil, 424: 619–638.

Grimes, C. et al. (2017). Report of the Review Workshop 1. Smart Mature Resilience Project Deliverable 5.3. https://smr-project.eu/fileadmin/user_upload/Documents/Resources/WP_5/D5.3.SMR_Report_ReviewWorkshop1.pdf (accessed March 2020).

Grizzetti, B. et al. (2016). Ecosystem services for water policy: Insights across Europe. Environmental Science and Policy, 66: 179-190.

Groeneveld, R. et al. (2019). Restoring marine ecosystems cost-effectively: lessons learned from the MERCES Project. MERCES Project Deliverable D7.4.

Grote, R. et al. (2016). Functional traits of urban trees in relation to their air pollution mitigation potential: A holistic discussion. Frontiers in Ecology and the Environment, 14: 543-550.

GrowGreen (2019). Monitoring and Evaluation: Measuring to improve decision making. GrowGreen Project Milestone 2.1a.

Guerreiro, S.B. et al. (2018). Future heat-waves, droughts and floods in 571 European cities. Environmental Research Letters, 13: 034009.

Guha-Sapir, D. (2016), Annual Disaster Statistical Review 2016: The Numbers and Trends. Brussels, CRED.

Guidolotti, G. et al. (2017). Promoting the potential of flux-measuring stations in urban parks: An innovative case study in Naples, Italy. Agricultural and Forest Meteorology, 233: 153-162.

Gurnell, A. et al. (2015). A multi-scale hierarchical framework for developing understanding of river behaviour to support river management. Aquatic Sciences, 78(1): 1-6.

Gusmaroli, G. et al. (2008). Contrat de Rivière as participative decision making tool to implement River Restoration. State of art in Italy and Agogna stream case study. In 4th ECRR International Conference on River Restoration, Venice, Italy.

Haase, A. (2017). The contribution of nature-based solutions to socially inclusive urban development–some reflections from a social-environmental perspective. In: N. Kabisch et al. (Eds.) Nature-Based Solutions to Climate Change Adaptation in Urban Areas. Springer, Cham: 221-236.

Haase, D. et al. (2017). Greening cities – to be socially inclusive? About the alleged paradox of society and ecology in cities. Habitat International: 41-48.

Hanania, S. & Anton, B. (2019). Co-designing NBSs in Living Labs. Report on workshop round 2 in Frontrunner Cities. ProGIreg Project Deliverable 2.4. https://progireg.eu/fileadmin/user_upload/Deliverables/D2.4_Report_on_WS_round_2_in_FRC_proGIreg_ICLEI_2019-10-01.pdf.

Hanley, N. & Black, A.R. (2006). Cost-benefit analysis and the Water Framework Directive in Scotland. International Environmental Assessment and Management 2(2): 156-165.

Hansen, R. et al. (2015). Report of Case Study City Portraits: Appendix - GREEN SURGE study on urban green infrastructure planning and governance in 20 European case studies. GREEN SURGE Project Deliverable https://greensurge.eu/filer/GREEN_SURGE_Report_of_City_Portraits.pdf (accessed March 2020).

Hansen, R. et al. (2017). Urban Green Infrastructure Planning: A Guide for Practitioners. GREEN SURGE

Project Deliverable 5.3. http://greensurge.eu/working-packages/wp5/ (accessed March 2020).

Hart, K. et al. (2017). Case study reports Developing innovative and participatory approaches for PG/ESS delivery. PEGASUS Project Deliverable 4.3.

Hartig, T. et al. (2011). Health Benefits of Nature Experience: Psychological, Social and Cultural Processes. In: K. Nilsson et al. (Eds.) Forests, Trees and Berlin: 127-168. Springer.

Hartmann, T., Slavíková, L. & McCarthy, S. (2019). Nature-based Flood Risk Management on Private Land - Disciplinary Perspectives on a Multidisciplinary Challenge. Springer, ISBN 978-3-030-23842-1

Hathway, E.A. & Sharples, S. (2012). The interaction of rivers and urban form in mitigating the Urban Heat Island effect: A UK case study. Built Environment, 58: 14-22.

Hawxwell, T. et al. (2018). Municipal Governance Guidelines. UNALAB Project Deliverable 6.2. https://unalab.eu/documents/d62-municipal-governance-guidelines

Hawxwell, T. et al. (2018). Municipal Governance Guidelines. UNALAB Project Deliverable 6.2. https://unalab.eu/system/files/2020-02/d62-municipal-governance-guidelines-2020-02-17.pdf (accessed March 2020).

Hering, D. et al. (2010). The European Water Framework Directive at the age of 10: A critical review of the achievements with recommendations for the future. Science of the Total Environment, 408. 4007-4019.

Hérivaux, C., Le Coent, P. & Gnonlonfin, A. (2019). Natural capital and ecosystem services to valuate cobenefits of NBS in water related risk management. NAIAD Project Deliverable 4.4. http://naiad2020.eu/wp-content/uploads/2019/09/D4_4_FINAL_Edited.pdf.

Hernández-Morcilloa, M. et al. (2018). Scanning agroforestry-based solutions for climate change mitigation and adaptation in Europe. Environmental Science and Policy, 80: 44–52.

Hiemstra, J.A., Saaroni, H. & Amorim, J.H. (2017). Urban Heat Island, thermal comfort and the role of urban green. In: D. Pearlmutter, C. Calfapietra & R. Samson (Eds.), The Urban Forest: Cultivating Green Infrastructure for People and the Environment, pp. 7-19. Springer International Publishing.

Hirabayashi, S., Kroll, C.N. & Nowak, D. J. (2012). Development of a distributed air pollutant dry deposition modelling framework. Environmental Pollution. 171: 9-17.

Holden, J. (2005). Peatland hydrology and carbon release: why small-scale process matters. Philosophical Transactions of the Royal Society A, 363(1837): 2891-2913.

Holden, J. et al. (2008). Overland flow velocity and roughness properties in peatlands. Water Resources Research, 44(6).

Holden, J., Gascoign, M. & Bosanko, N.R. (2007). Erosion and natural revegetation associated with surface land drains in upland peatlands. Earth Surface Processes and Landforms 32(10): 1547-1557.

Horton, B. et al. (2016). BeST (Benefits of SuDS Tool) W045c BeST - Technical Guidance Release version 2. (accessed 8 April 2020), http://observatoriaigua.uib.es/repositori/suds_herramientas_6.pdf

Hoyle, H., Hitchmough, J. & Jorgensen, A. (2017). Attractive, climate-adapted and sustainable? Public perception of non-native planting in the designed urban landscape. Landscape and Urban Planning, 164: 49-63.

Huang, J. J. et al. (2014). Assessing the performances of low impact development alternatives by long-term simulation for a semi-arid area in Tianjin, Northern China. Water Science and Technology 70: 1740–1745. doi:10.2166/wst.2014.228.

Hynes, S. et al. (2019). Valuing the Benefits from Marine Ecosystem Restoration: A Choice Experiment. MERCES Project Deliverable D7.3.

IEA (2018a). The Future of Cooling. https://www.iea.org/reports/the-future-of-cooling. Paris, IEA.

IEA (2018b). Air conditioning use emerges as one of the key drivers of global electricity-demand growth, Media Release. https://www.iea.org/news/air-conditioning-use-emerges-as-one-of-the-key-drivers-of-global-electricity-demand-growth. Paris, IEA.

IPBES (2017). IPBES Plenary 5 Decision IPBES-5/1: Implementation of the First Work Programme of the Platform, p23. www.ipbes.net/event/ipbes-5-plenary (accessed 15 March 2020).

Ishimatsu, K. et al. (2017). Use of rain gardens for stormwater management in urban design and planning. Landscape and Ecological Engineering, 13(1): 205–212. doi:10.1007/s11355-016-0309-3.

Iwaszuk, E. et al. (2019). Addressing Climate Change in Cities. Catalogue of Urban Nature-Based Solutions. Ecologic Institute, Berlin / Sendzimir Foundation, Krakow.

Izydorczyk, K. et al. (2019). The ecohydrological approach, SWAT modelling, and multi-stakeholder engagement - a system solution to diffuse pollution in the Pilica basin, Poland. Journal of Environmental Management, 248: 109329.

Jensen, I.H. et al. (2014). Demonstration of integrated real time control of sanitation systems incl. early warning for WQ in receiving waters in Aarhus. PREPARED Project Report 2014.047, Deliverable D1.3.4.

Jokinen, A. et al. (2016). How to enhance biodiversity in urban allotment gardens, Factsheet No. 9, Urban allotment gardens in European cities. https://www.urbanallotments.eu/09_FS_final_en4b49.pdf?id=252&type=0&jumpurl=uploads%2Fmedia%2F09_

FS_final_en.pdf&juSecure=1&locationData=252%3Att_content%3A606&juHash=301f5fd9ae064fda6458b026aedf1f8fb7a0f07d

Jones, J. et al. (2019). A comprehensive assessment of stream fragmentation in Great Britain. Science of the Total Environment, 673: 756-762.

Kabsich, N. et al. (2016a). Adding natural areas to social indicators of intra-urban health inequalities among children: a case study from Berlin, Germany. International Journal of Environmental Research & Public Health 13(8): 783.

Kabisch, N. et al. (2016b). Nature-based solutions to climate change mitigation and adaptation in urban areas: perspectives on indicators, knowledge gaps, barriers, and opportunities for action. Ecology and Society 21(2): 39.

Kabisch, N. et al. (2016c). Urban green space availability in European cities. Ecological Indicators, 70: 586–596.

Kabisch, N. et al. (Eds.) (2017). Nature-based Solutions to Climate Change Adaptation in Urban Areas. Springer.

Kadykalo, A. et al. (2019). Disentangling 'ecosystem services' and 'nature's contributions to people', Ecosystems and People, 15(1): 269-287.

Kail, J. & Wolter, C. (2011). Analysis and evaluation of large-scale river restoration planning in Germany to better link river research and management. River Research & Applications 27(8): 985-999.

Kampa, E. & Buijse, T. (2015). A fresh look on effective river restoration: Key conclusions from the REFORM project. Policy brief N°3. https://www.reformrivers.eu/system/files/REFORM_Policy_Brief_No3.pdf

Kang, C.D. & Cervero, R. (2009). From Elevated Freeway to Urban Greenway: Land Value Impacts of the CGC Project in Seoul, Korea. Urban Studies, 46: 2771–2794.

Kántor, N. et al. (2018). The Impact of Façade Orientation and Woody Vegetation on Summertime Heat Stress Patterns in a Central European Square: Comparison of Radiation Measurements and Simulations. Advances in Meteorology.

Kántor, N., Gulyás, Á. & Gál, C.V. (2017). Relevance of urban trees and sun shades regarding summertime heat stress reduction: field surveys from Pécs, Hungary. Proceedings of the 21st International Congress of Biometeorology, 2017. www.sciencedirect.com/science/article/pii/S016920461730261X?via%3Dihub

Kartha, S. & Dooley, K. (2016). The risks of relying on tomorrow's 'negative emissions' to guide today's mitigation action. Stockholm Environment Institute, Working Paper 2016-08.

Kay, P. et al. (2012). The effectiveness of agricultural stewardship for improving water quality at the catchment scale: experiences from an NVZ and ECSFDI watershed. Journal of Hydrology, 422-423: 10-16.

Kazmierczak, A. & Carter, J. (2010). Adaptation to climate change using green and blue infrastructure. A database of case studies. Interreg IVC GraBS project. University of Manchester, England.

Keating, K. et al. (2015). Cost estimation for SUDS - summary of evidence, Report –SC080039/R9, Environment Agency, Bristol. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/411509/Cost_estimation_for_SUDS.pdf (accessed March 2020)

Keeler, B.L. et al. (2019). Social-ecological and technological factors moderate the value of urban nature. Nature Sustainability, 2(1), 29–38.

Keesstra, S. et al. (2018). The superior effect of nature based solutions in land management for enhancing ecosystem services. Science of the Total Environment 610: 997–1009. doi: 10.1016/j.scitotenv.2017.08.077.

Kenward, R.E. et al. (2011). Identifying governance strategies that effectively support ecosystem services, resource sustainability and biodiversity. Proceedings of the National Academy of Sciences, 108(13): 5308-12.

Khan, U.T. et al. (2013). A data driven approach to bioretention cell performance: Prediction and design. Water (Switzerland) 5: 13–28. doi:10.3390/w5010013.

Khastagir, A. & Jayasuriya, L. N. N. (2010). Impacts of using rainwater tanks on stormwater harvesting and runoff quality. Water Science and Technology, 62: 324–329. doi:10.2166/wst.2010.283.

Kiss, B., Sekova, F. & Kotsila, P. (2019). International Comparison of Nature-Based Solutions. NATURVATION Project Report. https://naturvation.eu/sites/default/files/result/files/international_comparison_of_nbs.pdf

Kleerekopera, L., van Escha, M. & Baldiri Salcedob, T. (2012). How to make a city climate-proof, addressing the urban heat island effect. Resources, Conservation and Recycling, 64: 30–38.

Klijn, F. et al. (2013). Design quality of room-for-the-river measures in the Netherlands: role and assessment of the quality team (Q-team). International Journal of River Basin Management, 11: 287–299. doi:10.1080/15715124.2013.811418.

Knickel, K. & Maréchal, A. (2018). Stimulating the social and environmental benefits of agriculture and forestry: An EU-based comparative analysis. Land Use Policy, 73: 320-330.

Konarska, J. et al. (2016). Transpiration of urban trees and its cooling effect in a high latitude city. International Journal of Biometeorology, 60 (1), 159-172.

Kong, F. et al. (2017). Modeling stormwater management at the city district level in response to changes in land use and low impact development. Environmental Modelling and Software, 95: 132–142. DOI: 10.1016/j.envsoft.2017.06.021

Kovacs, A.S., Fulop, B. & Honti, M. (2012). Detection of Hot Spots of Soil Erosion and Reservoir Siltation in Ungauged Mediterranean Catchments, Energy Procedia, 18: 934-943.

Kroeger, T. et al. (2014). Reforestation as a novel abatement and compliance measure for ground-level ozone. Proceedings of the National Academy of Sciences, 111 (40): 4204-4213.

Krzeminski, P. et al. (2019). Performance of secondary wastewater treatment methods for the removal of contaminants of emerging concern implicated in crop uptake and antibiotic resistance spread: A review. Science of the Total Environment 648: 1052-1081.

Kumar, P. et al. (2019). The nexus between air pollution, green infrastructure and human health. Environment International, 133: 105181.

Langhout, W. (2019). The EU Biodiversity Strategy. Progress report 2011 – 2018. https://biodiversity.europa.eu/networks/LanghoutAdvies_2019_AssessmentReport20112018_EU_biodiversity_strategy_2020.pdf (accessed April 2020).

Lawrence, R. et al. (2019). Rethinking conceptual frameworks and models of health and natural environments. Health, 23(2): 158-79.

Lehmann, S. (2014). Low carbon districts: mitigating the urban heat island with green roof infrastructure. City, Culture and Society, 5: 1-8.

Li, Y.L. & Babcock, R.W. Jr. (2014). Green roof hydrologic performance and modeling: A review. Water Science and Technology, 69: 727–738.

Li, Z. et al. (2018). Objectives and indexes for implementation of sponge cities-A case study of Changzhou City, China. Water (Switzerland), 10(5): 623.

Lindberg, C.F. & Grimmond, S.B. (2011). The influence of vegetation and building morphology on shadow patterns and mean radiant temperatures in urban areas: Model development and evaluation. Theoretical and Applied Climatology, 105: 311-323.

Liquete C. et al. (2016). Integrated valuation of a nature-based solution for water pollution control. Highlighting hidden benefits. Ecosystem Services, 22: 392-401.

Loomis, D. et al. (2013). The carcinogenicity of outdoor air pollution. The Lancet Oncology, 14: 1262-1263.

Löschner, L. et al. (2019). Compensating flood retention on private land in Australia: towards polycentric governance in flood risk management? Landscape Architecture Frontiers, 7(3): 32–45. doi: 10.15302/J-LAF-1-020004.

Luan, Q. et al. (2017). Runoff Effect Evaluation of LID through SWMM in Typical Mountainous, Low-Lying Urban Areas: A Case Study in China. Water 9: 439. doi:10.3390/w9060439.

Lugato, E. et al. (2016). Quantifying the erosion effect on current carbon budget of European agricultural soils at high spatial resolution. Global Change Biology, 22(5), 1976–1984.

Maes, J. (2016). Mapping and Assessment of ecosystems and their services (MAES): Highlights and uncertainties of a science-policy interface on biodiversity and ecosystem services. Ekonomia I Środowisko, 4(59).

Maes, J. et al. (2013). Mapping and Assessment of Ecosystems and their Services, Agriculture, Ecosystems & Environment. Luxembourg, European Commission.

Maes, J. et al. (2015). ESS trends 2000-2012. Mapping and Assessment of Ecosystems and their Services: Trends in ecosystems and ecosystem services in the European Union between 2000 and 2010. Report EU 27143 EN.

Maes, J. et al. (2018a). Mapping and Assessment of Ecosystems and their Services: analytical framework for ecosystem condition. Luxembourg, Publications Office of the European Union.

Maes, J. et al. (2018b), Ecosystem services are inclusive and deliver multiple values. A comment on the concept of nature's contribution to people. One Ecosystem, 3: e24720.

Mantino, F., Vanni, F. & Forcina, B. (2016). Socio-political, economic and institutional drivers. A cross-country comparative analysis. Synthesis Report. PEGASUS Project Deliverable 3.3.

Marchal, R. et al. (2019). The (Re)Insurance Industry's Roles in the Integration of Nature-based Solutions for Prevention in Disaster Risk Reduction—Insights from a European Survey, Sustainability 11(22). DOI: 10.3390/su11226212.

Maréchal, A. et al. (2018). Policy lessons and recommendations from the PEGASUS project. PEGASUS Project Deliverable 5.4.

Mariani, L. et al. (2016). Climatological analysis of the mitigating effect of vegetation on the urban heat island of Milan, Italy. Science of the Total Environment, 569: 762–773.

Marsalek, J. (1991). Pollutant loads in urban stormwater: review of methods for planning level estimates. Water Resources Bulletin, 27(2): 283–291.

Marselle, M.R. et al. (2019). Biodiversity and Health in the Face of Climate Change. Springer.

Martin-Ortega, J. et al. (2014). Valuing water quality improvements from peatland restoration: Evidence and challenges. Ecosystem Services, 9: 34-43.

Martin, J. et al. (2019). NBS in-depth case study analysis of the characteristics of successful governance models. PHUSICOS Project Deliverable 5.1. https://phusicos.eu/wp-content/uploads/2019/12/D5_1_NBS-in-depth-case-study-analysis_Final-2.pdf (accessed March 2020).

Masi, F. et al. (2017). Constructed wetlands for combined sewer overflow treatment: Ecosystem services at Gorla Maggiore, Italy. Ecological Engineering, 98: 427-438.

Mateo-Sagasta, J. et al. (2017). Water pollution from agriculture: a global review. International Water Management Institute / Food and Agriculture Organisation of the UN (FAO), Rome.

May, L. & Spears, B.M. (2012). Loch Leven: 40 years of scientific research. Understanding the links between pollution, climate change and ecological response. Developments in Hydrobiology, 218: 130.

McGonigle, D.F. et al. (2012). Towards a more strategic approach to research to support catchment-based policy approaches to mitigate agricultural water pollution: A UK case-study, Environmental Science and Policy, 24: 4-14.

Mell, I.C. et al. (2013). Promoting urban greening: Valuing the development of green infrastructure investments in the urban core of Manchester, UK. Urban Forestry and Urban Greening, 12(3): 296-306.

Mendizabal, M. & Zorita, S. (2018). RESIN Adaptation Options Library. RESIN Project Deliverable 3.5. https://resin-cities.eu/fileadmin/user_upload/Resources/Adaptation_library/RESIN-D3.6_Completed_library_of_adaptation_options.pdf (accessed March 2020).

Meyer, V. et al (2015). Economic evaluation of adaptation options. BASE Project Deliverable 5.2 https://base-adaptation.eu/sites/default/files/Deliverable_5_2_FINAL.pdf.

Mielke, B. (2008). The costs and benefits of landscape quality enhancements on brownfield sites. In: CSI, 2008. Creating a Setting for Investment Project Report: 38-42. SYFP, Sheffield.

Mitchell, G. (2005). Mapping hazard from urban non-point pollution: a screening model to support sustainable urban drainage planning. Journal of Environmental Management, 74(1): 1-9.

Mitsch, W.J. & Gosselink, J.G. (2000). The value of wetlands: importance of scale and landscape setting. Ecological Economics, 35(1): 25-33.

Montalto, F. et al. (2007). Rapid assessment of the cost-effectiveness of low impact development for CSO control. Landscape and Urban Planning, 82(3): 117-131.

Morato, T. et al. (2018). Review on the principles of the deep-sea restoration and on the ecological benefits of passive and active restoration in the deep sea. MERCES Project Deliverable 4.1.

Morris E. P., Gomez-Enri J. & van der Wal D. (2015). Copernicus Downstream Service Supports Nature-Based Flood Defense: Use of Sentinel Earth Observation Satellites for Coastal Needs, Sea Technology Magazine. https://ris.utwente.nl/ws/portalfiles/portal/28126320/ST_Copernicus.pdf (accessed May 2020).

Morrow, O. (2019). Community Self-Organizing and the Urban Food Commons in Berlin and New York. Sustainability, 11(13): 3641.

Mukhtarov, F. et al. (2019). Collaborative learning for policy innovations: sustainable urban drainage systems in Leicester, England. Journal of Environmental Policy and Planning, 21(3): 288-301.

Mulligan, M. et al. (2019). Guidelines on the Eco:Actuary Policy Support System for understanding the role of Natural Flood Management (NFM) in flood mitigation. NAIAD Project Deliverable 2.5.

Nadin, V. & Stead, D. (2008). European spatial planning systems, social models and learning. disP - The Planning Review, 44 (172): 35-47.

Nagabhatla, N., Springgay, E. & Dudley, N. (2018). Forests as nature-based solutions for ensuring urban water security. Unasylva, 69(250): 43-52.

Nagase, A. & Koyama, S. (2020). Attractiveness and preference of extensive green roofs depend on vegetation types and past experience with plants in Japan, Urban Forestry & Urban Greening, Available online 21 March 2020, 126658, Journal Pre-proof, https://doi.org/10.1016/j.ufug.2020.126658.

Narayan, S. et al. (2016). The effectiveness, costs and coastal protection benefits of natural and nature-based defences. PLoS One 11(5):e0154735. https://doi.org/10.1371/journal.pone.0154735

National Audit Office (2010). Tackling diffuse water pollution in England. Report by the Comptroller and Auditor General. London, National Audit Office. HC 188 Session 2010-2011.

Naturvation (2019a). NBS Navigator, Technical Note: Carbon Storage Indicator. NATURVATION Project.

Naturvation (2019b). NBS Navigator, Technical Note: Air Temperature. NATURVATION Project.

Naturvation (2019c). NBS Navigator, Technical Note: PET. NATURVATION Project.

Naumann, S. & Davis, M. (2020). Biodiversity and Nature-based Solutions: analysis of EU-funded projects. EU Publications Office, Luxembourg.

Naumann, S. et al. (2018). Methodological review and framework: Cultural ecosystem services provided by green and blue infrastructure. ENABLE Project Deliverable 3.0.

Nesshöver, C. et al. (2017). The science, policy and practice of nature-based solutions: An interdisciplinary perspective. Science of the Total Environment, 579: 1215-1227.

Netusil, N.R. et al. (2014). Valuing green infrastructure in Portland, Oregon. Landscape and Urban Planning, 124: 14-21.

Newell-Price, J.P. et al. (2011). An Inventory of Mitigation Methods and Guide to their Effects on

Diffuse Water Pollution, Greenhouse Gas Emissions and Ammonia Emissions from Agriculture. Defra Project WQ0106: http://randd.defra.gov.uk

Ngai, R. et al. (2017). Working with Natural Processes – Evidence Directory. Appendix 2. Literature review. Project SC150005. Environment Agency, Bristol.

Nilsson, M. et al. (2018). Mapping interactions between the sustainable development goals: lessons learned and ways forward. Sustainability Science, 13: 1489–1503. https://doi.org/10.1007/s11625-018-0604-z.

Nisbet, T. et al. (2011) Woodland for Water: Woodland measures for meeting Water Framework Directive objectives. Forest Research Monograph, 4: 156. Forest Research, Surrey.

Nisbet, T.R. et al. (2012). Assessing the potential of woodland services for meeting Water Framework Directive Objectives. In: Proceedings of the SAC/SEPA Biennial Conference held at the University of Edinburgh on 3-4 April 2012: 20-25. SAC Auchincruive, Ayr.

Norton, B.A. et al. (2015). Planning for cooler cities: a framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes. Landscape and Urban Planning, 134: 127-138.

Novotny, V. & Olem, H. (1994). Water Quality: Prevention and Management of Diffuse Pollution. Van Nostrand-Reinhold, New York. ISBN 978-0442005597

Nowak D.J. et al. (2013). Urban forest structure, ecosystem services and change in Syracuse, NY. Urban Ecosystems, 19(4); 1455-1477.

Nowak, D.J. & Crane, D.E. (2002). Carbon storage and sequestration by urban trees in the USA. Environmental Pollution, 116: 381–389.

Nowak, D.J. et al. (2014). Tree and forest effects on air quality and human health in the United States. Environmental Pollution, 193: 119-129.

Oen, A.M.P. et al. (2019). PHUSICOS Work Package 1 Report. 776681_D1.4: 77.

ONS (2019). UK natural capital: peatlands. Office for National Statistics, Fareham. https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/uknaturalcapitalforpeatlands/naturalcapitalaccounts#executive-summary (accessed 12 March 2020).

OpenNESS (2017). Local Planning with Ecosystem Services and Stakeholder Participation. OpenNESS Brief No. 7. http://www.openness-project.eu/sites/default/files/Policy%20Brief_ES_local%20planning_final%20300817.pdf (accessed March 2020).

OPERAS (2018). What should the EU consider to move towards No Net Loss? OPERAS Policy brief. http://www.operas-project.eu/sites/default/files/resources/operas-a4-4pp-policybrief05-euconsidernnl-april2018.pdf

Oral, H.V. et al. (2020). A review of nature-based solutions for urban water management in European circular cities: a critical assessment based on case studies and literature. Blue-Green Systems, 2(1): 112-136.

Ossola, A. et al. (2018). The provision of urban ecosystem services throughout the private-social-public domain: a conceptual framework. Cities and the Environment 11(1):1.

Osterwalder, A., Pigneur, Y. & Tucci, C.L. (2005). Clarifying business models: origins, present, and future of the concept. Communications of the Association for Information Systems, 16(1). doi: 10.17705/1cais.01601.

Palmer, M.A., Filoso, S. & Fanelli, R.M. (2014). From ecosystems to ecosystem services: Stream restoration as ecological engineering. Ecological Engineering, 65: 62-70.

Palmer, M.A., Menninger, H.L. & Bernhardt, E. (2010). River restoration, habitat heterogeneity and biodiversity: A failure of theory or practice? Freshwater Biology, 55(1): 205-222.

Pauleit, S. et al. (2017). Nature-Based Solutions and Climate Change - Four Shades of Green. In: N. Kabisch et al. (eds.), Nature-based Solutions to Climate Change Adaptation in Urban Areas, Theory and Practice of Urban Sustainability Transitions. DOI 10.1007/978-3-319-56091-5_3.

Pauleit, S. et al. (2019). Advancing urban green infrastructure in Europe: Outcomes and reflections from the GREEN SURGE project. Urban Forestry and Urban Greening, 40: 4–16.

PEARL (2014). Policy Brief: Tailored stakeholder engagement: http://www.pearl-fp7.eu/wp-content/uploads/2018/07/Stakeholder-policy-brief-PEARL-FINAL.pdf (accessed March 2020).

PEGASUS (2016). The importance of social processes: unlocking synergies. Brief. http://pegasus.ieep.eu/system/resources/

Penchev, V. et al. (2019). Scope of Works for Demonstrators A and B. RECONECT Project Deliverable 2.3.

Pengal, P. et al. (2017). Catchment Characterization Report. NAIAD Project Deliverable 6.1. http://naiad2020.eu/wp-content/uploads/2018/07/D6_1.pdf

Perales-Momparler, S. et al. (2016). The role of monitoring sustainable drainage systems for promoting transition towards regenerative urban built environments: a case study in the Valencian region, Spain. Journal of Cleaner Production, 163: S113-S124. https://doi.org/10.1016/j.jclepro.2016.05.153.

Pérez-Soba, M. et al. (2016). Review of approaches and datasets to categorise and map Public Goods and Ecosystem Services at EU level. PEGASUS Project Deliverable 2.1.

Pérez-Soba, M. et al. (2016). Database and classification system of different types of PG/ESS in relation to farming/forestry systems. PEGASUS Project Deliverable 2.2.

Pérez-Soba, M. et al. (2018). Report on patterns and trends of Public Goods/Ecosystem Services in relation to land management systems. PEGASUS Project Deliverable 2.3.

PHUSICOS (2019). Governance innovation through nature-based solutions, IIASA Policy Brief. https://phusicos.eu/wp-content/uploads/2019/12/PB_25_Governance-innovation-through-nature-based-solutions_web.pdf

Piégay, H. et al. (2020). Remotely sensed rivers in the Anthropocene: state of the art and prospects. Earth Surface Processes and Landforms 45(1): 157-188.

Piet, G.J. et al. (2017). Making ecosystem-based management operational. AQUACROSS Project Deliverable 8.1.

Pinkham, R. (2000). Daylighting: New Life for Buried Streams. Old Snowmass, Colorado, Rocky Mountain Institute.

Plüddemann, A. et al. (2018). BMJ Evidence-Based Medicine, 23:201–203.

Pontee, N.I. et al. (2016). Building with nature: Lessons from around the world. Maritime Engineering Journal, 169(1): 29-36.

Priest, S.J. et al. (2016). The European Union approach to flood risk management and improving societal resilience: Lessons from the implementation of the Floods Directive in six European countries. Ecology and Society, 21: 50.

Pritchard, R. & Brockington, D. (2019). Forests: regrow with locals' participation. Nature, 569 (7758): 630.

Puttock, A. et al. (2017). Eurasian beaver activity increases water storage, attenuates flow and mitigates diffuse pollution from intensively-managed grasslands. Science of the Total Environment, 576: 430-443.

Qiao, X.J., Kristoffersson, A. & Randrup, T.B. (2018). Challenges to implementing urban sustainable stormwater management from a governance perspective: A literature review. Journal of Cleaner Production, 196: 943–952 DOI: 10.1016/j.jclepro.2018.06.049

Qin, H.P., Li, Z.X. & Fu, G. (2013). The effects of low impact development on urban flooding under different rainfall characteristics. Journal of Environmental Management, 15(129): 577-85.

Randrup, T.B. et al. (2020). Moving beyond the nature-based solutions discourse: introducing nature-based thinking. Urban Ecosystems: 1-8.

Raymond, C.M. et al. (2017). A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas. Environmental Science and Policy, 77: 15-24.

Renaud, F. (2019). Review on vulnerability and risk assessment specific to NBS. OPERANDUM Project Deliverable 6.1. https://www.operandum-project.eu/wp-content/uploads/D6.1_NBS_vulnerability_risk_assessment.pdf (accessed March 2020).

Rica, M. et al. (2017). Institutional analysis report: baseline analysis and policy recommendations. NAIAD Project Deliverable 3.2.

Richter, S. et al. (2013). The Water Framework Directive as an approach for Integrated Water Resources Management: Results from the experiences in Germany on implementation, and future perspectives. Environmental Earth Sciences, 69(2): 719-728.

Rijke, J. et al. (2012) Room for the River: delivering integrated river basin management in the Netherlands, International Journal of River Basin Management, 10(4): 369-382.

Rosenfeld, A.H. et al. (1998). Cool communities: strategies for heat island mitigation and smog reduction. Energy and Building, 28: 51-62.

Rosenzweig, C. et al. (2015). ARC3.2 summary for city leaders. In: Urban Climate Change Research Network. New York, Columbia University.

Rouillard, J. et al. (2017). Protecting aquatic biodiversity in Europe: How much do EU environmental policies support ecosystem-based management? Ambio, 47: 15-24.

Ruangpan, L. et al. (2020). Nature-based solutions for hydro-meteorological risk reduction: a state-of-the-art review of the research area. Natural Hazards and Earth System Sciences 20: 243–270. doi:10.5194/nhess-20-243-2020.

Ruggie, J. (2004). Reconstituting the global public domain: issues, actors and practices. Journal of International Relations, 10 (4): 499–531.

Saaroni, H. et al. (2018). Urban Green Infrastructure as a tool for urban heat mitigation: Survey of research methodologies and findings across different climatic regions. Urban Climate, 24: 94: 110.

Salbitano, F. et al. (2016). FAO Guidelines on urban and peri-urban forestry. Food & Agriculture Organization of the UN, Rome. http://www.fao.org/3/a-i6210e.pdf

Samson, R. et al. (2017). Urban Trees and Their Relation to Air Pollution. In: D. Pearlmutter et al. (Eds.) The Urban Forest - Cultivating Green Infrastructure for People and the Environment, pp. 21-30. Springer.

Santamouris, M. (2014). Cooling the cities - a review of reflective and green roof mitigation technologies to fight heat island and improve comfort in urban environments. Solar Energy, 103, 682-703.

Saraev, V. (2012). Economic benefits of greenspace: a critical assessment of evidence of net economic benefits. Forestry Commission Research Report. Edinburgh, Forestry Commission.

Scartazza, A. et al. (2020). Caring local biodiversity in a healing garden: Therapeutic benefits in young subjects with autism. Urban Forestry and Urban Greening, 47: 126511.

Schirmer, M. et al. (2014). Morphological, hydrological, biogeochemical and ecological changes and challenges in river restoration – the Thur River case study. Hydrology and Earth Systems Sciences, 18: 2449–2462.

Schleyer, C. et al. (2015). EU FP7 OpenNESS Project Deliverable 2.1, Paper on the Policy Analysis. Stahre, P., 2006. Sustainability in Urban Storm Drainage – Planning and Examples. Malmö, VAforsk.

Schleyer, C. et al. (2015). Policy analysis of key regulatory frameworks within Europe. OpenNESS Project Deliverable 2.1.

Schmalzbauer, A. (2018). Barriers and success factors for effectively co-creating NBS for urban regeneration. CLEVER Cities Project Deliverable 1.1.1. https://clevercities.eu/fileadmin/user_upload/Resources/D1.1_Theme_1_Barriers_success_factors_co-creation_HWWI_12.2018.pdf (accessed March 2020).

Scholes, L., Revitt, D.M. & Ellis, J.B. (2008). A systematic approach for the comparative assessment of stormwater pollutant removal potentials. Journal of Environmental Management, 88(3): 467-478.

Schwarz, N. et al. (2017). Understanding biodiversity-ecosystem service relationships in urban areas: A comprehensive literature review. Ecosystem Services, 27: 161-171.

Seddon, N. et al. (2020). Understanding the value and limits of NBS to climate change and other global challenges. Philosophical Transactions of the Royal Society B, 375: 20190120.

Sekulova, F. & Anguelovski, I. (2017). The Governance and Politics of Nature-Based Solutions, NATURVATION Project Deliverable 1.3 Part VII. https://naturvation.eu/sites/default/files/news/files/naturvation_the_governance_and_politics_of_nature-based_solutions.pdf (accessed March 2020).

SEPA (2004). National Water Classification 2004. https://www.sepa.org.uk/media/38540/water-quality-classification-2004.pdf. Scottish Environment Protection Agency, Falkirk.

Settele, J. et al (2020). COVID-19 Stimulus measures must save lives, protect livelihoods and safeguard nature to reduce the risk of future pandemics. IPBES Expert Guest Article, 27 April 2020. https://ipbes.net/covid19stimulus (accessed April 2020).

Sgrigna, G. et al. (2020). Relationships between air particulate matter capture efficiency and leaf traits in twelve tree species from an Italian urban-industrial environment. Science of The Total Environment, 718: 137310

Shafique, M., Kim, R. & Kyung-Ho, K. (2018). Rainfall Runoff Mitigation by Retrofitted Permeable Pavement in an Urban Area. Sustainability 10: 1231. doi:10.3390/su10041231.

Sharp, R.J.A., Ewald, J.A. & Kenward, R.E. (2011) Policy recommendations and Guidelines. TESS: Transactional Environmental Support System. http://www.tess-project.eu/downloads/TESS%20policy%20recommendations%20and%20guidelines.pdf

Simpson, J.R. & Mcpherson, E.G. (2011). The tree BVOC index. Environmental Pollution, 159: 2088-2093.

Skidmore, A.K. et al. (2019). Comment on "The global tree restoration potential". Science, 366: 6469. doi:10.1126/science.aaz0111

Smid, M. et al. (2019). Ranking European capitals by exposure to heat waves and cold waves. Urban Climate, 27: 388-402.

Soini, K. et al. (2019). Multi Stakeholder Engagement Strategy. OPERANDUM Project Deliverable D8.1. https://www.operandum-project.eu/wp-content/uploads/D8.1_Multistakeholder_engagement_strategy-2.pdf (accessed March 2020).

Speak, A.F., Mizgajski, A. & Borysiak, J. (2015). Allotment gardens and parks: Provision of ecosystem services with an emphasis on biodiversity. Urban Forestry and Urban Greening, 14: 772–781.

Steyaert, P. & Ollivier, G. (2007). The European Water Framework Directive: how ecological assumptions frame technical and social change. Ecology and Society 12(1): 25.

Stovin, V. (2010). The potential of green roofs to manage urban stormwater. Water and Environment Journal, 24(3): 192-199.

Stovin, V. et al. (2015). The influence of substrate and vegetation configuration on green roof hydrological performance. Ecological Engineering, 85: 159-172.

Stovin, V. et al. (2017). Defining green roof detention performance. Urban Water Journal, 14(6): 574-588.

Stovin, V., Vesuviano, G. & Kasmin, H. (2012). The hydrological performance of a green roof test bed under UK climatic conditions. Journal of Hydrology, 414: 148-161. doi:10.1016/j.jhydrol.2011.10.022.

SEEDS (2015). SEEDS Final Report: Stimulating Enterprising Environments for Development and Sustainability. Sheffield, South Yorkshire Forest Partnership.

Tapper, N. et al. (2019). Estimating the economic benefits of Urban Heat Island mitigation - Biophysical Aspects. Melbourne, Cooperative Research Centre for Water Sensitive Cities

Teixeira, R. (2010). Sustainable land uses and carbon sequestration: the case of sown biodiverse permanent pastures rich in legumes. Dissertação para obtenção do Grau de Doutor em Engenharia do Ambiente. Lisbon, Técnica de Lisboa, Instituto Superior Técnico

Teixeira, R. (2015). Sown Biodiverse Pastures: A nature-based approach to reverse the degradation of Mediterranean ecosystems. Nature-Based Solutions Workshop, June 2 2015, Brussels. Presentation. https://www.biodiversa.org/883/download

Tiwari, A. et al. (2019). Considerations for evaluating green infrastructure impacts in microscale and macroscale air pollution dispersion models. Science of The Total Environment, 672: 410-426.

Tosics, I. (2013). Sustainable land use in peri-urban areas: government, planning and financial instruments. In: K. Nillson et al. (Eds.) Peri-urban futures: scenarios and models for land use change in Europe: 373-404. Springer.

Toxepeus, H. (2019). Taking action for urban nature: Business Model Catalogue. NATURVATION Project. https://naturvation.eu/sites/default/files/results/content/files/business_model_catalogue.pdf

Toxopeus, H. et al. (2020). Structural Conditions for Integrating Nature-Based Solutions: Finance Domain. NATURVATION Project Deliverable 5.3.

Triguero-Mas, M. et al. (2017) The effect of randomised exposure to different types of natural outdoor environments compared to exposure to an urban environment on people with indications of psychological distress in Catalonia. Plos One: 0172200.

Trinomics & Wood (2019). Fitness Check Evaluation of the Water Framework Directive & the Floods Directive. Study contract for European Commission DG ENV.

Tsakiris G., Nalbantis I. & Pistrika A. (2009). Critical Technical Issues on the EU Flood Directive. European Water, 25/26: 39-51.

Turkelboom, F. et al. (2017). Local Planning with Ecosystem Services & Stakeholder Participation. OpenNESS Project Brief No. 7. http://www.openness-project.eu/sites/default/files/Policy%20Brief_ES_local%20planning_final%20300817.pdf (accessed March 2020).

Turnheim, B. et al. (2015). Evaluating sustainability transitions pathways: Bridging analytical approaches to address governance challenges. Global Environmental Change, 35: 239–253.

Turnhout, E. et al. (2020). The politics of co-production: participation, power, and transformation. Current Opinion in Environmental Sustainability, 42:15–21.

Twohig-Bennett, C. & Jones, A. (2018). The health benefits of the great outdoors: A systematic review and meta-analysis of greenspace exposure and health outcomes. Environmental Research, 166: 628-37.

UN (1992). UN Conference on Environment and Development: Agenda 21 Action Plan for the Next Century. UN CED, Rio de Janeiro, June 1992.

UN (2017). Habitat III: The New Urban Agenda. http://habitat3.org/the-new-urban-agenda/ (accessed May 2020).

UCCRN (2018). Impact 2050: The Future of Cities Under Climate Change, UCCRN Technical Report for C40 Cities Climate Leadership. https://c40-production-images.s3.us-west-2.amazonaws.com/impact2050report.pdf (accessed March 2020).

UNECE (1998). Aarhus Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters. UN Economic Commission for Europe, Aarhus, Denmark www.unece.org/env/pp/treatytext.htm.

UNISDR (2015). Sendai Framework for Disaster Risk Reduction 2015–2030. In: UN world conference on disaster risk reduction, 2015 March 14–18, Sendai, Japan. Geneva: United Nations Office for Disaster Risk Reduction. Available at http://www.unisdr.org/files/43291_sendaiframeworkfordrren.pdf (accessed March 2020).

Urban GreenUp (2019). Societal Challenge Catalogue. UrbanGreenUp Project Deliverable 1.2.

URBANGAIA (undated) MapNat information sheet: Mapping the use of nature. https://naturvation.eu/sites/default/files/results/content/files/business_model_catalogue.pdf

URBES (2012). URBES Factsheet N°2: Biodiversity and ecosystem services: the foundation for human health and well-being. www.iucn.org/sites/dev/files/import/downloads/urbes_factsheet_02_web.pdf

URBES (2014). URBES Factsheet N°6: Green infrastructure, a wealth for cities. www.iucn.org/sites/dev/files/import/downloads/urbes_factsheet_06_web.pdf

Vallecillo, S. et al. (2016). Synergies and conflicts between the delivery of different ES and biodiversity conservation: Spatial planning for investment in green infrastructure and ecosystem restoration across the EU. OpenNESS Project Deliverable 3.3.

van den Bosch M. & Sang, A.O. (2017). Urban natural environments as nature-based solutions for improved public health - a systematic review of reviews. Environmental Research, 158: 373-384.

van der Jagt, S. et al. (2019). Structural Conditions for Integrating Nature-Based Solutions: Regulatory Domain. NATURVATION Project Deliverable 5.2.

Van Eerd, M.C.J., Wiering, M.A., & Dieperink, C. (2015a), Solidarity in transboundary flood risk management: a view from the Dutch North Rhine-Westphalian catchment area. Climate Policy:1-19. http://dx.doi.org/10.1080/14693062.2015.1075376

Van Eerd, M.C.J., Dieperink, C. & Wiering. M.A. (2015b). 'A dive into floods': exploring the Dutch implementation of the Floods Directive. Water Policy, 17(2):187-207. http://dx.doi.org/10.2166/wp.2014.025.

van Slobbe, E. et al. (2013). Building with Nature: In search of resilient storm surge protection strategies. Natural Hazards, 66(3): 1461-1480. doi:10.1007/s11069-013-0612-3.

Verdonschot, P.F.M. et al. (2013). A comparative review of recovery processes in rivers, lakes, estuarine and coastal waters. Hydrobiologia, 704(1): 453-474.

Versini, P.A. et al. (2018). A distributed modelling approach to assess the use of Blue and Green Infrastructures to fulfil stormwater management requirements. Landscape & Urban Planning, 173: 60–63. doi:10.1016/j.landurbplan.2018.02.001.

Verweij, P. et al. (2016). QUICKScan as a quick and participatory methodology for problem identification and scoping in policy processes. Environmental Science & Policy, 66: 47-61.

Vierikko, K. et al. (2015). Biocultural diversity - concept and assessment. GREEN SURGE Project Deliverable 2.1.

Vierikko, K. et al. (2017). BCD: Linkages between people and nature – Database, typology and indicators. GREEN SURGE Project Deliverable MS22.

Vinten, A.J.A. et al. (2004). Appraisal of rural BMPs for controlling diffuse pollution and enhancing biodiversity. SNIFFER Project WFD13. Edinburgh, SNIFFER.

Vojinovic, Z. (2020). Nature-based Solutions for flood mitigation and coastal resilience: analysis of EU-funded projects. EU Publications Office, Luxembourg.

Vojinovic, Z. et al. (2016a). Holistic approach to flood risk assessment in urban areas with cultural heritage: a practical application in Ayutthaya, Thailand, Natural Hazards, Springer, DOI: 10.1007/s11069-015-2098-7.

Vojinovic, Z. et al. (2016b). Combining ecosystem services with cost-benefit analysis for selection of green and grey infrastructure for flood protection in a cultural setting. Environments, 4(1): 3. doi:10.3390/environments4010003.

Watkin L.J. et al. (2019). A Framework for Assessing Benefits of Implemented Nature-Based Solutions, Sustainability, 11(23):6788. DOI: 10.3390/su11236788.

WEF (2020). Nature Risk Rising: Why the Crisis Engulfing Nature Matters for Business and the Economy. WEF, Geneva.

Westling, E.L. et al. (2014). Developing adaptive capacity through reflexivity: lessons from collaborative research with a UK water utility. Critical Policy Studies, 8(4): 427-446.

Westling, E.L. et al. (2019). Reflexive adaptation for resilient water services: Lessons for theory and practice. Global Environmental Change, 57: 101937.

Westerlink, J. & van Doorn, A. (2016). Case study 'Skylark' (Netherlands). Pegasus project deliverable D4.1(23). http://pegasus.ieep.eu/case-studies/list-of-case-studies#netherlands (accessed April 2020).

Whiteoak, K. & Saigar, J. (2019). Estimating the economic benefits of Urban Heat Island mitigation-Economic Analysis. Melbourne, Cooperative Research Centre for Water Sensitive Cities.

WHO (2016). Urban Green Space and Health: Interventions Impacts and Effectiveness. http://www.euro.who.int/en/health-topics/environment-and-health/urban-health/publications/2016/urban-green-spaces-and-health-a-review-of-evidence-2016 (accessed March 2020).

WHO (2020). WHOQOL: Measuring Quality of Life. https://www.who.int/healthinfo/survey/whoqol-qualityoflife/en/ (accessed March 2020).

Wild, T. (2020). Nature-based Solutions: improving water quality and waterbody conditions – analysis of EU-funded projects. EU Publications Office, Luxembourg.

Wild, T.C., Dempsey, N. & Broadhead, A.T. (2019). Volunteered information on nature-based solutions - Dredging for data on deculverting. Urban Forestry and Urban Greening, 40: 254-263.

Wild, T.C. et al. (2003). An Evaluation of SUDS and Urban Diffuse Pollution and Reference Material. Proceedings of the Second National Conference on Sustainable Drainage Coventry University.

Wild, T.C. et al. (2011). Deculverting: Reviewing the evidence on the 'daylighting' and restoration of culverted rivers. Water and Environment, 25(3): 412-421.

Wild, T.C. & Henneberry, J.M. (2020). Nature-based solutions and water challenges: financing an accelerated transition to more sustainable cities using NBS. In C. Herzog et al. (Eds.). EU-Brazil Sector Dialogue on Nature-Based Solutions. EC, Brussels. ISBN: 978-92-76-18445-4; doi:10.2777/95912

Wild, T.C., Henneberry, J.M. & Gill, L. (2017). Comprehending the multiple 'values' of green infrastructure - valuing nature-based solutions for urban water management from multiple perspectives. Environmental Research, 158: 179-187. doi: 10.1016/j.envres.2017.05.043.

Wild, T.C., Jefferies, C. & D'Arcy, B.J. (2002). SUDS in Scotland - the Scottish SUDS database. SNIFFER Final Report SR(02)09. Edinburgh, SNIFFER.

Wild, T.C., Ogden, S. & Lerner, D.N. (2008). An innovative partnership response to the management of urban river corridors -Sheffield's River Stewardship Company. 11th International Conference on Urban Drainage, Edinburgh. IAHR/IWA.

Winkler, K. & Schleyer, C. (2015). Policy Analysis: Water Framework Directive. http://www.openness-project.eu/sites/default/files/OpenNESS%20D2.1 %20Paper%20on%20the%20policy%20analysis%20WP2_ANNEXES.pdf.

Wong, T. (2006). Australian Runoff Quality: A Guide to Water Sensitive Urban Design. ISBN 0 85825 852 8, Engineers Australia, Canberra, Australia.

World Bank (2015). https://www.worldbank.org/en/news/press-release/2015/10/13/addressing-the-youth-employment-crisis-needs-urgent-global-action (accessed 25 March 2020.

Xie, L. & Bulkeley, B. (2020). City for Biodiversity: the Roles of Nature-based Solutions in European cities. NATURVATION. https://naturvation.eu/sites/default/files/news/files/city_for_biodiversity_the_roles_of_nature-based_solutions_in_european_cities.pdf

Yang, J. et al. (2005). The urban forest in Beijing and its role in air pollution reduction. Urban Forestry and Urban Greening, 3: 65-78.

Zawadzka, J. et al. (2019). Ecosystem services from combined natural and engineered water and wastewater treatment systems: Going beyond water quality enhancement. Ecological Engineering, X (2): 100006.

Zhou, Q. (2014). A Review of sustainable urban drainage systems considering the climate change and urbanization impacts. Water, 6: 976-992.

Zölch, T. et al. (2017). Regulating urban surface runoff through nature-based solutions – An assessment at the micro-scale. Environmental Research, 157: 135–144. DOI: 10.1016/j.envres.2017.05.023.

Zwartkruis, J. et al. (2015). Analysis of green niche-innovations and their momentum in the two pathways. Country report 12: Green niche-innovations in the Dutch land-use system. PATHWAYS Project Deliverable 2.1.

Zwartkruis, J., Westhoek, H. & Kok, M. (2016). Forward-looking analysis of transition pathways. Sub-report: The land use domain in the Netherlands. PATHWAYS Project Deliverable 2.5.

ANNEX 1. LIST OF REVIEWED PROJECTS

AMBER (Adaptive Management of Barriers in European Rivers). H2020, Jun 2016 – Sep 2020, EU contribution €6,020,172, project link

AQUACROSS (Knowledge, Assessment, and Management for AQUAtic Biodiversity and Ecosystem Services aCROSS EU policies), H2020, Jun 2015 – Nov 2018, EU contribution: €6,343,614, project link

AQUANES (Demonstrating synergies in combined natural and engineered processes for water treatment systems), H2020, Jun 2016 – May 2019, EU contribution: €7,837,292, project link

AQUAVAL (Sustainable Urban Water Management Plans, promoting SUDS and considering Climate Change, in the Province of Valencia), LIFE, Jan 2010 – Sep 2013, EU contribution: €499,458, project link

ARTS (Accelerating and Rescaling Transitions to Sustainability), FP7, Dec 2013 – Nov 2016, EU contribution: € 2 996 826, project link

ASTI (Forecasting System for Urban Heat Island Effect), LIFE+, Sep 2018 – Aug 2021, EU contribution: €736,823, project link

BASE (Bottom-up Climate Adaptation Strategies towards a Sustainable Europe), FP7, Oct 2012 – Sep 2016, EU contribution: €5,899,442, project link

BESAFE (Biodiversity and Ecosystem Services: Arguments for our future Environment), FP7, Sep 2011 - Aug 2015, EU contribution: €3,009,973, project link

BIOMOT (MOTivational strength of ecosystem services and alternative ways to express the value of BIOdiversity), FP7, Sept 2011 – Aug 2015, EU contribution: €3,152,839, project link

BLUEHEALTH (Linking Up Environment, Health And Climate For Inter-Sector Health Promotion And Disease Prevention In A Rapidly Changing Environment), H2020, Jan 2016 – Jun 2020, EU contribution: €5,998,671, project link

BRIGAID (BRIdges the GAp for Innovations in Disaster resilience), H2020, May 2016 – Apr 2020, EU contribution: €7,739,806, project link

BRIDGE (sustainaBle uRban plannIng Decision support accountinG for urban mEtabolism), FP7, Dec 2008 - Nov 2011, EU contribution: €3,100,000, project link

CASCADE (Community Safety Action for Supporting Climate Adaptation and Development), DG ECHO (European Union Civil Protection and Humanitarian Aid), Jan2019 – Dec 2020, Budget: €850,871, project link

CLARITY (Integrated Climate Adaptation Service Tools for Improving Resilience Measure Efficiency), H2020, Jun 2017 – May 2020, EU contribution: €4,999,999, project link

CLEARING HOUSE (Collaborative Learning in Research, Information-sharing and Governance on How Urban tree-based solutions support Sino-European urban futures), H2020, Sep 2019 – Aug 2023, EU contribution: €4,986,464, project link

CLEVER CITIES (Co-designing Locally tailored Ecological solutions for Value added, socially inclusivE Regeneration in Cities), H2020, Jun 2018 – May 2023, EU contribution: €14,214,661, project link

CONEXUS (CO-producing Nature-based solutions and restored Ecosystems: transdisciplinary neXus for Urban Sustainability), H2020, Sep 2020 – Aug 2024, EU contribution: €4,999,940, project link

CONNECTING (Connecting Nature), H2020, Jun 2017 – May 2022, EU contribution: €11,394,282, project link

CLIMARK (Forest management promotion for climate change mitigation through the design of a local market of climatic credits), LIFE, Oct 2017 – Sep 2021, EU contribution = €716,947, project link

DESSIN (Demonstrate Ecosystem Services Enabling Innovation in the Water Sector), FP7, Jan 2014 – Dec 2017, EU contribution €5,980,942, project link

ECOADAPT (Ecosystem-based strategies and innovations in water governance networks for adaptation to climate change in Latin American Landscapes), FP7, Jan 2012 – Jan 2016, EU contribution: €1,899,000, project link

ECONADAPT (Economics of climate change adaptation in Europe), FP7, Oct 2013 – Sep 2016, €2,928,618, project link

ECOPOTENTIAL (Improving future ecosystem benefits through earth observations), H2020, Jun 2015 – Oct 2019, EU contribution: €14,874,340, project link

EKLIPSE (Establishing a European Knowledge and Learning Mechanism to Improve the Policy-Science-Society Interface on Biodiversity and Ecosystem Services), H2020, Feb 2016 – Jul 2020, EU contribution: €2,997,272, project link

EKOROB (ECOtones for Reducing Diffusion Pollution), LIFE+, Jan 2010 - Sep 2015, EU contribution: €624,368, project link

ENABLE (Enabling Green and Blue Infrastructure Potential in Complex Social-Ecological, project link Regions), BiodivERsA, Dec 2016 – May 2020, Total grant: €2,540,309 (co-funded by the EU), project link

ENROUTE (Enhancing Resilience of urban ecosystems through green infrastructure), JRC project, Dec 2016 – Feb 2018, project link

ESMERALDA (Enhancing ecoSysteM sERvices mApping for poLicy and Decision mAking), H2020, Feb 2015 – Jul 2018, EU contribution: €3,002,166, project link

GREEN4GREY (Innovative design & development of multifunctional green & blue infrastructure in Flanders grey peri-urban landscapes), LIFE, Jul 2014 – Dec 2019, EU contribution: €1,671,415, project link

GREENINURBS (Green Infrastructure approach: linking environmental with social aspects in studying and managing urban forests), COST, Feb 2013 – Jun 2017, EU contribution: €706,000, project link

GREEN SURGE (Biocultural diversity, green infrastructure and ecosystem services), FP7, Nov 2013 – Oct 2017, EU contribution: €5,701,837, project link

GRIN (Promoting urban integration of GReen INfrastructure to improve climate governance in cities), LIFE, Jun 2018 – Dec 2021, EU contribution: €1,015,505, project link

GROW GREEN (Green Cities for Climate and Water Resilience, Sustainable Economic Growth, Healthy Citizens and Environments), H2020, Jun 2017 - May 2020, EU contribution: €11,224,058, project link

IMAGINE (Integrative Management of Green Infrastructures Multifunctionality, Ecosystem integrity and Ecosystem Services: From assessment to regulation in socioecological systems), BiodivERsA, Feb 2017 – Jan 2020, Total grant: €1,495,876 (co-funded by the EU), project link

INHERIT (INter-sectoral Health Environment Research for InnovaTions), H2020, Jan 2016 – Dec 2019, EU contribution: €5,952,903, project link

INTERLACE (International cooperation to restore and connect urban environments in Latin AmeriCa and Europe), H2020, Sep 2020 – Aug 2024, EU contribution: €5,476,165, project link

ISCAPE (Improving the Smart Control of Air Pollution in Europe), H2020, Sep 2016 – Aug 2019, EU contribution: €5,850,829, project link

LAND4FLOOD LAND4FLOOD (Natural Flood Retention on Private Land), COST Action, Sep 2017 – Sep 2021, project link

MARS (Managing Aquatic ecosystems and water Resources under multiple Stress), FP7, Feb 2014 – Jan 2018, EU contribution: €8,996,782, project link

MERCES (Marine Ecosystem Restoration in Changing European Seas), H2020, Jun 2016 – May 2020, EU contribution: €6,651,118, project link

MOORLIFE (Moor Life 2020), LIFE+, Oct 2015 – Feb 2021, EU contribution: €11,984,887, project link

NAIAD (Nature Insurance Value: Assessment & Demonstration), H2020, Dec 2016 – May 2020, EU contribution: €4,994,370, project link

NATURAL COURSE (Integrated water management approach to delivery of the North West England River basin management plan). LIFE-IP, Jan 2015 – Dec 2019, EU contribution: €11,988,811, project link

NATURE4CITIES (Nature Based Solutions for re-naturing cities: knowledge diffusion and decision support platform through new collaborative models). H2020, Nov 2016 – Oct 2020, EU contribution: €7,499,981, project link

NATURVATION (NATure-based URban innoVATION), H2020, Nov 2016 – Oct 2020, EU contribution: €7,797,878, project link

OPENNESS (Operationalization of natural capital and ecosystem services), H2020, Dec 2012 – May 2017, EU contribution: €8,999,193, project link

OPERANDUM (OPEn-air laboRAtories for Nature baseD solUtions to Manage environmental risks), H2020, Jul 2018 – Jun 2022, EU contribution: €12,257,343, project link

OPERAS (Operational Potential of Ecosystem Research Applications), FP7, Dec2012 – Nov 2017, EU contribution: €8,997 910, project link

OPTWET (Finding optimal size and location for wetland restoration sites for best nutrient removal performance using spatial analysis and modelling), H2020, Apr 2015 – Mar 2018, EU contribution: €240,507, project link

PATHWAYS (Transition pathways to sustainable low carbon societies), FP7, Dec 2013 – Nov 2016, EU contribution: €2,998,498, project link

PEARL (Preparing for Extreme And Rare events in coastaL regions), FP7, Jan 2014 – Apr 2018, EU contribution: € 4 998 851,04, project link

PEGASUS (Stimulating long-lasting improvements in the delivery of social, economic and environmental benefits from PEARL agricultural and forest land), H2020, Mar 2015 – Feb 2018, EU contribution: €2,977,525, project link

PHENOTYPE (Positive health effects of natural outdoor environments in typical populations in different regions in Europe), FP7, Jan 2012 – Dec 2015, EU contribution: €3,499,403, project link

PHUSICOS ("According to nature": Solutions to reduce risk in mountain landscapes), H2020, May 2018 - Apr 2022, EU contribution: €9,472,200, project link

PLACARD (PLAtform for Climate Adaptation and Risk reduction), H2020, June 2015 – May 2020, EU contribution: € 2 852 760, project link

POWER (Political and sOcial awareness on Water EnviRonmental challenges), H2020, Dec 2015 – Nov 2019, EU contribution: €3,747,938, project link

PREPARED (Prepared Enabling Change). FP7, Feb 2010 – Jan 2014, EU contribution €6,993,815, project link

PROGIREG (productive Green Infrastructure for post-industrial urban regeneration: nature for renewal), H2020, Jun 2018 – May 2023, EU contribution: €10,432,512, project link

RAMSES (Reconciling Adaptation, Mitigation and Sustainable Development for Cities), FP7, Oct 2012 – Sep 2017, EU contribution: €5,200,000, project link

RECONECT (Regenerating ECOsystems with Nature-based solutions for hydro-meteorological risk rEduCTion), H2020, Sep 2018 – Aug 2023, EU contribution: €13,520,690, project link

RECREATE (REsearch network for forward looking activities and assessment of research & innovation prospects in the fields of Climate, Resource Efficiency & raw mATErials), H2020 Jul 2013 – Jun 2018, EU contribution: €2,996,868, project link

REFORM (Restoring rivers for effective catchment management), FP7, Nov 2011 – Oct 2015, EU contribution: €6,997,603, project link

REGREEN (Fostering nature-based solutions for smart, green and healthy urban transitions in Europe and China), H2020, Sep 2019 – Aug 2023, EU contribution €4,996,172, project link

RESCUE (River flood Embankments Subject to Climate change: Understanding Effects of future floods and novel 'low-carbon' adaptation measures), FP7, May 2014 – Sep 2016, EU contribution: €231,283, project link

RESCCUE (Resilience to Cope with Climate Change in Urban Areas), H2020, May 2016 – Apr 2020, EU contribution: €6,896,992, project link

RENATURE (Promoting Research Excellence in NAture-based soluTions for innovation, sUstainable economic GRowth and human wEll-being in Malta), H2020, Sep 2018 – Aug 2021, EU contribution: €995,885, project link

RESIN (Climate Resilient Cities and Infrastructures), H2020, May 2015 – Oct 2018, EU Contribution: €7,466,004, project link

RISC-KIT (Resilience-Increasing Strategies for Coasts – toolkit), FP7, Nov 2013 – Apr 2017, EU contribution: €5,999,692, project link

RISES-AM (Responses to coastal climate change: Innovative Strategies for high End Scenarios - Adaptation and Mitigation), FP7, Nov 2013 – Oct 2016, EU contribution: €,4,407,648, project link

ROBIN (Role Of Biodiversity In climate change mitigatioN), FP7, Nov 2011 – Oct 2015, EU contribution: €6,985,678, project link

SCALLUVIA (Habitat Restoration of alluvial forests and creeks within the flood controlled Scheldt estuary site Kruibeke-Bazel-Rupelmonde), LIFE+, Sep 2013 – Aug 2018, €1,744,732, project link

SHARECITY (Sustainability of City-Based Food Sharing), ERC, Oct 2015 – Jul 2021, EU contribution: €1,860,009, project link

SECOA (Solutions for Environmental contrasts in COastal Areas), FP7, Dec 2009 – Nov 2013, EU contribution: €,6,159,118, project link

SIMETORES Urban Adaptation And Community Learning For A Resilient Simeto Valley, LIFE, Jun 2018 – Dec 2021, EU contribution: € 568 037, project link

SMR (Smart Mature Resilience), H2020, Jun 2015 – Jun 2018, EU contribution: €4,641,233, project link

SOIL4WINE (Innovative approach to soil management in viticultural landscapes), LIFE+, Jan 2017 – Dec 2019, EU contribution: €914,999, project link

TESS (Transactional Environmental Support System), FP7, Oct 2008 - Jun 2011, EU contribution: €1,801,112, project link

THINKNATURE (Development of a multi-stakeholder dialogue platform and Think tank to promote innovation with Nature based solutions), H2020, Dec 2016 – Nov 2019, EU contribution: €2,974,164, project link

TREECHECK (Green Infrastructure Minimising the Urban Heat Island Effect), LIFE+, Sep 2018 – Aug 2022, EU contribution: €944,000, project link

TURAS (Transitioning towards Urban Resilience and Sustainability), FP7, Oct 2011 – Sep 2016, EU contribution: € 6,813,819, project link

UNALAB (Urban Nature Labs), H2020, Jun 2017 – May 2020, EU contribution: €12,768,932, project link

URBAN ALLOTMENTS, COST action, Oct 2012 – Oct 2016, project link

URBANGAÏA (Managing urban Biodiversity and Green Infrastructure to increase city resilience), BiodivERsA, Mar 2017 – Feb 2020, Total grant: € 692,715 (co-funded by the EU), project link

URBAN GREENUP (New Strategy for Re-Naturing Cities through Nature-Based Solutions), H2020, Jun 2017 – May 2020, EU contribution: €13,970,642, project link

URBES (Urban Biodiversity and Ecosystem Services), BiodivERsA, 2010-2011: € 2,662,281, project link
URBINAT (Healthy corridors as drivers of social housing neighbourhoods for the co-creation of social, environmental and marketable NBS), H2020, Jun 2018 – May 2023, EU contribution: €13,019,300, project link
WISER (Water bodies in Europe: Integrative Systems to assess Ecological status and Recovery), FP7, Mar 2009 – Feb 2012, EU contribution: € 6,984,092, project link

ANNEX 2. METHODOLOGY

This document is a synthesis of reports provided by six independent experts, contracted by the EC to undertake the analysis and 'valorisation' of NBS project results. The work was completed between November 2019 and May 2020. The overall methodology was set out in the terms of reference for experts' contracts. Projects that would be the main focus for the review and valorisation were identified by the EC, and a full list of projects reviewed is provided in Annex 2. These selected studies, referred to by the EC as the 'Stricto Sensu' EU NBS projects, were primarily but not exclusively funded under the H2020 and FP7 programmes. Experts were also asked to draw on their background knowledge and use their own judgement to include findings from other projects and from scientific literature within the review. Projects reviewed within each of the substantive sections on 'policy challenge' areas are listed in the separate reports provided by the individual experts.

Public deliverables for those projects (and, where requested and agreed, some draft or confidential deliverables) were reviewed for their results and impacts, in terms of relevant outcomes for pre-defined policy challenge areas. The appointed experts discussed at length what would be classed as results and impacts of projects, including strategic outcomes such as capacity-building results, as well as various different forms of evidence resulting from innovative research and implementation actions.

Workshops were held in Brussels during December 2019 and January 2020, to discuss and agree the approach, to support scoping, and to provide evidence. The first workshop included a range of policy stakeholders, the project team, and DG RTD and EASME staff with expertise in EU projects and NBS-relevant topics. The second workshop entailed a progress review, with experts presenting their work to date, discussing emerging findings and planning next steps. Regular teleconferences were held and augmented by email exchanges, telephone calls and file-sharing between project team members and DG RTD and EASME staff. Coordinators of Horizon 2020 projects were consulted by EASME to contribute knowledge about project outcomes, and to seek their insights into research and innovation gaps as well as future policy development needs.

The above screenings of EU NBS project outcomes were complemented by scientific reviews, whereby individual experts were requested to examine the state of the art within specific realms of knowledge. Project results were framed within this wider (global) knowledge base, to provide context and improve the prospects for uptake of the findings. This framing of NBS project outcomes also helped to identify key areas for policy development and gaps in NBS research and innovation. A restricted review methodology was adapted (after Plüddemann, A. et al., 2018). The overall 'protocol' applied was as described above. Experts employed a range of different platforms and systems including Scopus, Web of Science and Google Scholar, as well as their existing knowledge of the literature.

Definitions and keyword search terms were agreed and circulated within the project team, so that individual experts could help one another to identify relevant deliverables using appropriate terms and language for the respective policy challenge areas. This also facilitated the 'snowballing' of awareness of the wider literature to ensure greater coverage but also specificity in searches, according to particular policy areas (and also to help delineate between different search areas to minimise duplication).

International platforms on NBS knowledge were also used to complement the study of project deliverables and the wider literature. In particular these included the Oppla Marketplace, the Naturvation Urban Nature Atlas, the World Bank supported Natural Hazards NBS platform and other resources including the NBS Initiative. These assets were used to both screen for relevant project outcomes and also for the proofing of findings, to ensure that the most relevant and impactful results had been captured wherever possible.

Reviews of each resulting draft report were undertaken by DG RTD and EASME staff, and between individual experts. Each review involved analysing gaps and commenting on substantive, process and presentational aspects of the reporting. The resulting reports were abridged by individual experts to provide shorter 'policy factsheets', to be published separately by the EC. The full set of documents was then synthesised and edited during April-May 2020, as presented in this report.

ANNEX 3. ABBREVIATIONS AND ACRONYMS

ADHD	Attention Deficit Hyperactivity Disorder
AMR	Antimicrobial Resistance
BGI	Blue-Green Infrastructure
BMPs	Best Management Practices
CAP	Common Agricultural Policy
CBA	Cost-Benefit Analysis
CEC	Contaminants of Emerging Concern
CIS	Common Implementation Strategy (Water Framework Directive)
COST	Cooperation in Science and Technology Programme
CO2	Carbon Dioxide
CSO	Combined Sewer Overflow
CSA	Coordination and Support Action (Framework Programme)
EASME	Executive Agency for Small and Medium-sized Enterprises
EBA	Ecosystem-based Adaptation
EBM	Ecosystem-based Management
EC	European Commission
ECJ	Court of Justice of the European Union
Eco-DRR	Ecosystem-based Disaster Risk Reduction
ECOSTAT	Ecological Status Working Group (Water Framework Directive)
EEA	European Environment Agency
ERDF	European Regional Development Fund
ESIF	European Structural and Investment Funds
EU	European Union
FD	Floods Directive
FP6	6th Framework Programme
FP7	7th Framework Programme
GEP	Good Ecological Potential
GHG	Greenhouse Gases
GI	Green Infrastructure
GIS	Geographical Information Systems
GVA	Gross Value-Added
GWD	Groundwater Directive
H2020	Horizon 2020 EU Framework Programme for Research & Innovation
HMWB	Heavily Modified Water Bodies
IA	Innovation Action (Framework Programme)
IPBES	Intergovernmental Platform on Biodiversity & Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
JPI	Joint Programming Initiative
KTM	Key Types of Measures

LID	Low Impact Development
MAES	Mapping and Assessment of Ecosystems and their Services
MS	Member States of the EU
NBS	Nature-based Solutions
NCFF	Natural Capital Financing Facility
NCP	Nature's Contributions to People
ND	Nitrates Directive
NFM	Natural Flood-risk Management
NGO	Non-Governmental Organisation
NWRM	Natural Water Retention Measures
PoM	Programme of Measures
RBMP	River Basin Management Plan
RIA	Research and Innovation Action (Framework Programme)
SDG	Sustainable Development Goals
SME	Small and Medium Sized Enterprises
SUDS	Sustainable Urban Drainage Systems
UN	United Nations
UWWTD	Urban Waste Water Treatment Directive
WFD	Water Framework Directive
WHO	World Health Organisation
WSUD	Water Sensitive Urban Design
WTP	Willingness-To-Pay
WWTW	Waste Water Treatment Works

ANNEX 4. NBS PROJECT PORTFOLIO IN HORIZON 2020

URBAN GreenUP

New Strategy for Renaturing Cities through Nature Based Solutions.

MAIN OBJECTIVES:

- URBAN GreenUP is the demonstration of an innovative methodology to re-naturing cities for adaptation to climate change, through for example the concept of Re-naturing Urban Planning (RUP) which incorporates the urban planning aspects directly related to the nature-based solutions as part of the Sustainable Urban Planning and delivering a procedure to support the direct implementation of NBS for specific climate change risks.

DEMONSTRATION SITES:

- Liverpool: SUDs, Urban carbon sink, Urban Catchment forestry, planting trees, pollinator verges, pollinator roof, floating gardens, mobile gardens, Green façade, New Green Cycle route, etc.
- Valladolid: Pollinator's modules, planting trees, SUDS, Green noise barriers, Green covering shelter, Green roof, Green façade, Urban garden Biofilter, cycle and pedestrian green paths, vertical mobile gardens, etc.
- Izmir: Parklets, planting trees, urban carbon sink, pollinator's modules, Green fences, Fruit walls, Climate-smart Greenhouses, Cool pavements, Green shady structures, etc.

MOST INNOVATIVE TOOL:

- NBS Selection Tool
- NBS Catalogue and Societal Challenges Catalogue for NBS
- Guidelines to city zoning

URBAN GreenUP is the promoter of Nature Based Solutions Cooperation Manifesto

EU contribution **€13 970 642.25**
Start-End **2017-2022**

www.urbangreenup.eu

UNaLab

The overarching objective of UNaLab is to develop, via co-creation with stakeholders and implementation of 'living lab' demonstration areas, a robust evidence base and European framework of innovative, replicable, and locally-attuned nature-based solutions to enhance the climate and water resilience of cities.

INNOVATIVE TOOLS:

- UNaLab NBS Co-Creation Toolkit
- Urban Living Lab Playground game
- Open Nature Innovation Arena
- Urban Living Lab Framework
- NBS Technical Handbook
- NBS Infographic
- UNaLab project video
- NBS video
- NBS Performance and Impact Monitoring Guide
- City Performance Monitor
- NBS Simulation and Visualisation Tool
- UNaLab Municipal Governance Guidelines
- NBS Business Models and Financing Strategies
- NBS Value Chain Analysis
- NBS Value Model

NBS IN EINDHOVEN (NL)

Green roof, green façade, watercourse daylighting, water stockage areas (retention ponds, detention basins), streambank restoration, urban trees.

NBS IN GENOVA (IT)

Benicalap-Green wall, green roof, sustainable urban forest, green corridor to reduce heat stress.

NBS IN TAMPERE (FI)

Olbin- greening of residential courtyards and a green street to reduce heat stress and water run off.

Green façade

Afforestation of steep slopes

Stormwater treatment wetland

EU contribution **€12 768 931,75** Start-End **2017-2022**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 730052 | Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

www.unalab.eu

GROW GREEN

Green Cities for Climate and Water Resilience, Sustainable Economic Growth, Healthy Citizens and Environments

The overarching aim of Grow Green to deliver systemic changes to the long-term planning, development, operation and management of Cities through the use of NBS, in order to deliver quantified improvements in climate and water resilience, social, environmental and economic performance.

PROJECT OBJECTIVES

- Contribute to the evidence base of nature-based solutions in cities.
- Develop an easy-to-use replicable approach to support the development and implementation of NBS strategies in cities.
- Determine the required conditions to support, drive and enable the implementation of city NBS strategies

INNOVATIVE NBS TOOLS

GrowGreen Compendium of Nature Based Solutions
Approaches to Financing NBS
Managing flooding with NBS Video

NBS IN MANCHESTER (EN)

A new community park with Sustainable Urban Drainage features including planted swales, bio retention tree pits, rain gardens, permeable paving.

NBS IN VALENCIA (ES)

Benicalap-Green wall, green roof, sustainable urban forest, green corridor to reduce heat stress.

NBS IN WROCLAW (PL)

Olbin- greening of residential courtyards and a green street to reduce heat stress and water run off.

Planted swale

Green wall

Green courtyard

EU contribution **€11 224 058** Start-End **2017-2022**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 730283 | Topic: SCC-2-2016-2017: Innovative NBS in Cities

www.growgreenproject.eu

CONNECTING NATURE

COproductioN with NaturE for City Transitioning, INnovation and Governance.

OVERALL AIM:

Connecting Nature is innovating with nature to co-create climate resilience in cities. The project aims to co-develop the policy and practices necessary to scale up urban resilience, innovation and governance using nature-based solutions

INNOVATIVE TOOLS:

- Connecting Nature Framework – scaling out nature-based solutions
- Reflexive Monitoring – silo busting
- UrbanbyNature – programme for establishing a nature-based solutions approach
- Financing and Business Models
- Nature-based enterprise platform – networking
- Technical solutions
- Governance
- Impact assessment - NBS dashboard (health & well-being)
- Co-production

GLASGOW

The City of Glasgow Open Space Strategy is a long-term vision for the city's open spaces, providing a framework for a biodiversity action planning, as well as food growing and sports pitch strategies, and nature-based solutions.

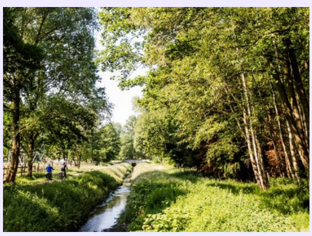
GENK

The City of Genk has developed a strategic plan to regenerate the Stiemer Vallei and the regeneration of a degraded water way and active travel route that runs through the heart of the city, connecting key sites across the city through nature-based solutions.

POZNAŃ

The City of Poznań is working with schools on a programme of small-scale green interventions across the city to supplement the 'green wedges' nature-based solutions in the city.

Glasgow (UK)



Genk (Belgium)

Poznań (Poland)

EU contribution **€11 400 000** Start-End **2017-2022**

https://connectingnature.eu

PROGIREG

Dortmund (DE), Turin (IT) and Zagreb (HR) are creating Living Labs in urban areas which face the challenge of post-industrial regeneration. proGIreg Living Labs will develop NBS which are citizen owned and co-developed by state, market and civil society stakeholders.

Dortmund: Leisure activities and clean energy on former landfills, Community-based urban farms and gardens, Aquaponics, Accessible green corridors, Pollinator biodiversity

Turin: New regenerated soil, Community-based urban farms and gardens, Aquaponics, Green walls and roofs, Accessible green corridors, Local environmental compensation processes, Pollinator biodiversity

Zagreb: Community-based urban farms and gardens, Aquaponics, Green walls and roofs, Accessible green corridors, Local environmental compensation processes

Ningbo: New regenerated soil, Accessible green corridors, Local environmental compensation processes

Follower cities: Cascais (PT), Cluj-Napoca (RO), Piraeus (GR) and Zenica (BA).

MOST INNOVATIVE TOOLS:

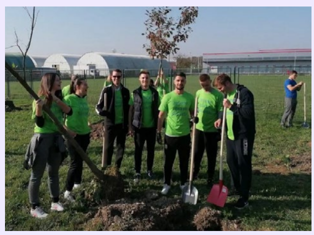
- Guidelines for co-designing and co-implementing green infrastructure in urban regeneration processes
- Methodology on spatial analysis in front-runner and follower cities

VIDEOS:

- proGIreg project video
- How to attract more butterflies and bees to your city

Dortmund

Turin



Zagreb

EU contribution **€10 432 512.01**
Start-End **2018-2023**

www.progireg.eu

URBiNAT

URBiNAT [Urban Inclusive and Innovative Nature] – Healthy corridors as drivers of social housing neighbourhoods for the co-creation of social, environmental and marketable NBS.

URBiNAT aims to promote an inclusive urban regeneration process of social housing neighbourhoods, where citizens and stakeholders are engaged in a co-creation process to implement a Healthy Corridor that combines territorial and technological NBS with participatory and solidarity economy ones, in seven European cities: a) frontrunners – Porto, Nantes, Sofia; b) followers – Hoje Taastrup, Brussels, Siena, Nova Gorica

Innovative tools The URBiNAT innovative tools to co-create NBS are being designed and tested with the cities:

- Co-Creation Process to establish the stages for the development of the Healthy Corridor
- Strategy of Municipal Roadmap to support the co-creation process
- SuperBarrio App to co-select and co-design NBS

PORTO (PT)

Healthy Corridor combining material and immaterial solutions, such as sensorial garden, natural amphitheater, urban farm, solidarity market, cultural mapping

NANTES (FR)

Healthy Corridor connecting natural capital, social assets and innovation: Green loops, Canada Park, rivercourse restoration, urban farm, testing Superbarrio App

SOFIA (BG)

Healthy Corridor gathering citizens and stakeholders for a new and more inclusive economy: farmers network, bread houses, mineral water pools

Social and Solidarity NBS, Solidarity Market, Porto, 2019. Photo: URBiNAT

Participatory NBS, Super Barrio App, Nantes, 2019. Photo: URBiNAT

Social and Solidarity NBS, Bread houses, Sofia, 2019. Photo: Laura Ohler

EU contribution **€13 019 300**
Start-End **2018-2023**

www.urbinat.eu

EdiCitNet

EdiCitNet aims to develop a sustainable network of cities, empowering their inhabitants with a common methodology to explore the wealth and diversity of existing ECS. A common knowledge base will help city administrations implement ECS in their specific contexts.

MAIN GOAL:

Making cities around the world better places to live through real-life implementation and anchoring Edible City Solutions (ECS) in urban planning. EdiCitNet is demonstrating ECS going one step further: We include the whole chain of urban food production, distribution and utilisation for inclusive urban regeneration and address societal challenges such as mass urbanisation, social inequality, climate change and resource protection in cities.

EdiCitNet Innovation

Interactive Toolbox

Rotterdam

Business Consulting Team

Oslo

Edible Cities Network

Andernach

Market Place

Berlin

EU contribution **€11,300,000**
Start-End **2018-2023**

www.edicitnet.com

CLEVER Cities

Co-designing Locally tailored Ecological solutions for Value added, socially inclusivE Regeneration in Cities.

- CLEVER Cities aims at demonstrating the added value of NBS in an urban regeneration context. Interventions are to display innovation pathways towards a nature-based transformation of the partner cities. They address multiple challenges: loss of biodiversity, climate change, increasing demographic diversity, social inclusion, environmental injustice and a relative lack of economic prosperity in certain parts of the cities.
- Interventions are co-designed, co-implemented, co-monitored and co-managed by local public, private and civil society stakeholders working together in Urban Innovation Platforms (UIPs).
- Front-runner cities implement CLEVER Action Labs (CALs): Hamburg, London and Milan
- Followers: Belgrade (RS), Larissa (EL), Madrid (ES), Malmö (SE), Quito (EC), and Sfantu Gheorghe (RO).

HAMBURG (DE)

Green corridor through pilot area, green roofs and facades, rain water management, green school yards

LONDON (UK)

Green corridor through pilot area, implementation of „healthy streets“ concept, collaborative re-design of green spaces, revitalisation of water body

MILAN (IT)

Green roofs and facades, collaborative re-design of green spaces, green noise barriers

EU contribution **€14 860 000**
Start-End **2018-2023**

www.clevercities.eu

PHUSICOS

Aims to demonstrate that nature-based and nature-inspired solutions for reducing the impact of extreme weather events in rural mountain landscapes, are technically viable, socially acceptable, cost-effective and implementable at the regional scale. Tools being developed and applied include a Living Labs approach to engage stakeholders, a framework for comparative analysis and monitoring to evaluate the performance as well as identifying key governance enablers of successful NBS.

NBS INNOVATION TOOLS:

- Framework for NBS Assessment
- Living Labs Guiding Framework
- Stakeholder Knowledge Mapping Starter Toolbox
- NBS Successful Governance Models
- Web-based Inventory of NBS (module 1)

THE PYRENEES (FR, ES)

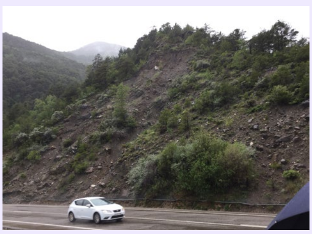
Reintroducing old methods of terracing with revegetation against erosion and rock fall, use of local timber constructions to reduce energy of rockfall, and afforestation in snow avalanche release areas for snow stabilization.

SERCHIO RIVER BASIN (IT)

Vegetated buffer strips along irrigation canals, to improve flooding and drought related problems and prevent runoff of sediments, and pollutants from farmland to Lake Massaciuccoli.

VALLEY OF GUDBRANDSDALEN (NO)

Receded green barriers increase flood area to reduce river energy and restore riparian vegetation, restoration of old minidams delays flooding in problematic tributary rivers.



EU contribution **€9 500 000**
Start-End **2018-2022**

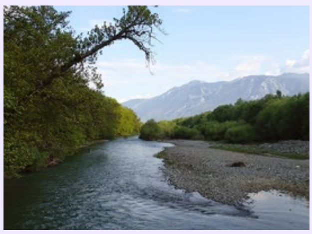
phusicos.eu

OPERANDUM

Aims to provide science-evidence for the usability of NBS, best practices for their design based on participatory processes. Foresees a multiple level of stakeholders engagement acceptance to promote NBS diffusion and establishes the framework for the strengthening of NBS-based policies.

- OPERANDUM is based on open-air laboratories (OALs), a concept that expands the Living Labs to a wider vision for natural and rural areas.
- OBJECTIVE is to reduce hydro-meteorological risks in European territories through green and blue/grey/hybrid NBS and push their business exploitation.

OAL Watten Valley (AT)



OAL Spercheios river (GR)

OAL Lake Puruvesi (FI)

OAL Elbe Valley (DE)

OAL Po Valley (IT)

EU contribution **€12 300 00**
Start-End **2018-2022**

www.operandum-project.eu/

RECONECT

Regenerating ECOsystems with Nature-based solutions for hydro-meteorological risk rEduCTion (RECONECT).

RECONECT aims to contribute to European and International reference frameworks on Nature-Based Solutions (NBS) by demonstrating, referencing and upscaling large-scale NBS and by stimulating a new culture for 'land use planning' that links the reduction of hydro-meteorological risks (e.g., floods, storm surges, landslides and droughts) with local and regional development objectives in a sustainable way. RECONECT will demonstrate the performance and feasibility of Nature-Based Solutions in a number of Demonstration and Collaboration sites.

Demonstrators A – NBS are planned and will be implemented during the lifetime of the project

Dove/Gose Elbe Estuary, Germany


Tordera River Basin, Spain

Portofino Regional Natural Park, Italy

Demonstrators B – NBS already exist


IJssel River Basin, The Netherlands


Aarhus, Egå Engsø and Lystrup, Denmark


Les Boucholeurs, France

EU contribution **€13 520 689.64**
Start-End **2018-2023**

www.reconect.eu

NAIAD

NAIAD aims to operationalise the insurance value of ecosystems for water-related risk mitigation, by developing and testing concepts, tools and applications on 9 demo sites across Europe, under the common concept of Nature Based Solutions (NBS).

- **Rotterdam**, Urban water buffer, Bio filtration, Buffer/retention, Aquifer Storage & Recovery (ASR), Constructed wetlands.
- **Lower Danube Basin**, Reconnecting the Danube flood plain, restoring the former ponds and setting up forest windbreak network in order to achieve the flood peak reduction; increasing the quality and quantity of green areas and biodiversity.
- **Thames Basin**, Regenerative agriculture (changes in soil tillage to improve infiltration), Retention ponds (mainly on farmland), and Leaky Dams.
- **Brague Basin**, Natural water retention areas, giving room to the river, Floodplain restoration and management.
- **Medina Aquifer**, MAR (managed aquifer recharge), Crop change, Soil conservation, Reforestation, Small dams, Water re-use.
- **Glinščica catchment**, Dry retention areas, re-meandering & re-vegetation, opening natural floodplains.
- **Lez Basin**, City de-proofing (completed with local grey infrastructures which allow infiltration as permeable pavements), Bioswales, Open vegetated retention basin, Green roofs, Vegetated Flood expansion area (floodplains), Flood extension area (Wetlands), Watercourses renaturation and minimum space for well-functioning, Riparian buffers , Karst active management.
- **Copenhagen**, Restored Urban River.
- **Lodz**, Biofilters, buffer zones, detention basins, reservoirs, pocket wetlands, rain gardens.

NBS TOOLS:

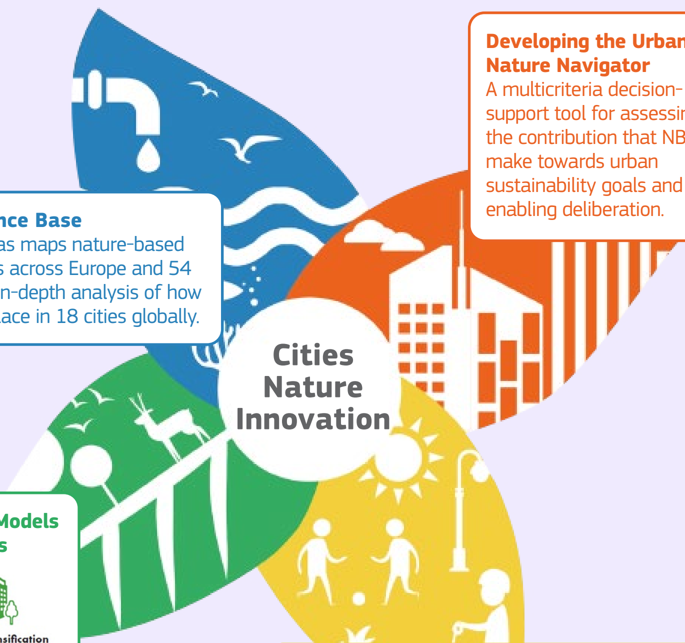
- Eco:actuary Toll Kit;
- The «Flood-Excess-Volume» Method;
- Financing Framework for Water Security;
- Integrated collaborative modelling approach;
- A classification scheme for NBS selection processes;
- CAT Model;
- Economic Assessment Framework;
- NAS Canvas;
- Participatory Modelling for NBS design and assessment;
- The Stakeholder Engagement Protocol;
- Massive Online Open Course "Greening Risk Reduction with Nature Based Solutions"

EU contribution **5 081 176.25**
Start-End **2016-2020**

www.naiad2020.eu

NATURVATION

Aims to advance assessment, enable innovation and build momentum for the uptake of NBS in cities across Europe. The project brings together 14 partners across six EU countries and a wide variety of stakeholders in six urban-regional innovation partnerships supported by a high level taskforce.



Developing the Urban Nature Navigator
A multicriteria decision-support tool for assessing the contribution that NBS make towards urban sustainability goals and enabling deliberation.

Building the Evidence Base
The Urban Nature Atlas maps nature-based solutions in 100 Cities across Europe and 54 case-studies provide in-depth analysis of how innovation is taking place in 18 cities globally.

Creating Business Models & Financing Options

Risk reduction
Green densification
Local stewardship
Green health

Generating Governance Solutions
Identifying tools to bridge the opportunity gap between policy drivers and action on the ground, modes of governance, key principles for sustaining NBS and promising pathways for mainstreaming.

EU contribution **€7 800 000**
Start-End **2016-2020**

www.naturvation.eu

NATURE4CITIES

Nature Based Solutions for re-naturing cities: knowledge diffusion and decision support platform through new collaborative models.

Nature4Cities aims at raising awareness about NBS and foster new collaborative models for NBS uptake by developing a knowledge and decision support platform.

This platform offers an integration framework of interconnected tools/services to provide access to NBS knowledge, and to complete the NBS assessment process of benefits, co-benefits and costs of NBS projects: NBS project creation, urban, socio-economic and environmental impact evaluation and final NBS project implementation, including tools to manage stakeholder's participation.

Nature4Cities Platform
Implementation Model Database
Geocluster4NBS
Citizen's Say
EQOL Scale
Social acceptance of and barriers for NBS projects implementation
N4C Step-By-Step Guide






EU contribution **7 499 981,25**
Start-End **2016-2021**

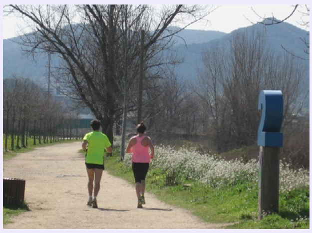
www.nature4cities.eu

INTERLACE

International Cooperation to Restore and Connect Urban Environments in Latin America and Europe.

Aims to strengthen EU-CELAC cooperation on (peri)urban ecological restoration and rehabilitation; foster participatory engagement to promote restorative NBS; increase the capacity of local governments to implement integrated and ecologically coherent urban planning and governance approaches; inspire and support learning and exchange on restorative NBS between cities and raise awareness and understanding of the benefits of healthy (peri)urban ecosystems for social, cultural and economic wellbeing.

Restoration of wetland, river corridor & green belt. Envigado, CO



Brownfield rehabilitation, river restoration. Granollers, ES

Brownfield rehabilitation. Chemnitz, DE

River restoration, restoring ecological connectivity. Portoviejo, EC

Park and urban forest restoration. CBIMA, CR

Restoring ecological connectivity, urban parks and forests. Krakow Metropolis, PL

EU contribution **€5 480 000**
Start-End **2020-2024**

CONEXUS

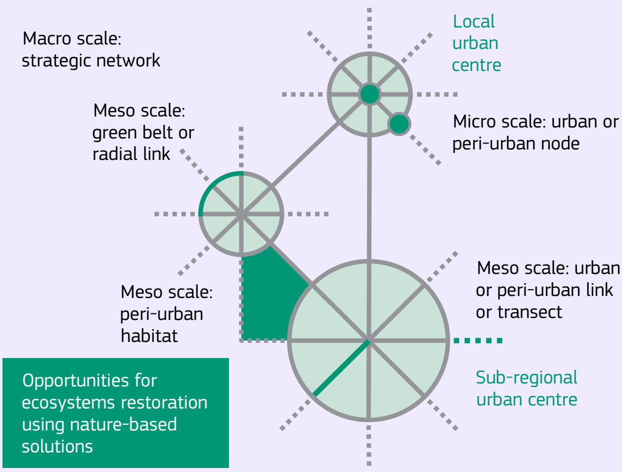
Bringing together European and Latin American partners sharing the purpose to strengthen international cooperation on nature-based solutions (NBS) and ecosystem restoration.

CONEXUS will co-produce, structure and promote access to the shared, contextualised knowledge needed to support cities and communities to co-create nature-based solutions and together restore urban ecosystems to help drive the required step-change in urban policy and practice in Europe and Latin American countries.

Our focal cities share common challenges of sustainable urbanisation and are united by their extensive experience, transdisciplinary approach and vision to implement place-based NBS and nature-based thinking.

CONEXUS transdisciplinary partnership: brings together NBS policy, practice andresearch, engaging citizens in innovative 'Life-Labs': urban and peri-urban ecosystem restoration pilots in EU & CELAC cities.

São Paulo — Bogotá — Santiago — Buenos Aires — Lisbon — Barcelona — Turin



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 867564

tinyurl.com/conexus-project

CLEARING HOUSE

Collaborative Learning in Research, Information-Sharing and Governance on how Urban Forests as Nature-based Solutions support Sino-European Urban Futures

The main objective of CLEARING HOUSE is to analyse and develop – across China and Europe – the potential of urban forests as nature-based solutions for enhancing the resilience of cities facing major ecological, socio-economic, and human wellbeing challenges.

EU contribution **€5 000 000**
Start-End **2019-2023**

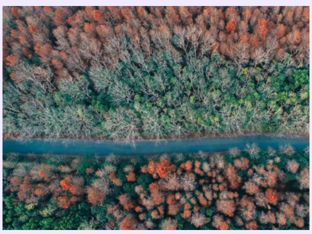
www.clearinghouseproject.eu

REGREEN

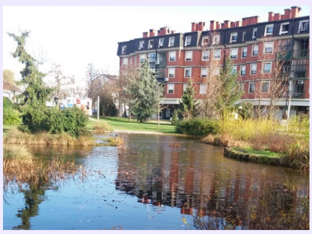
Fostering nature-based solutions for equitable, green and healthy urban transitions in Europe and China

Aims to integrate knowledge and evidence on benefits from NBS to address urban challenges; develop and test tools to guide, design and plan NBS; consolidate business and investment models for NBS and promote NBS awareness and institutionalisation in education, governance, and planning

- Children & youth's experience & awareness of natural environment & NBS
- Quantifying and modelling ecosystem services from NBS
- Quantifying benefits & values from NBS and their services
- Improve systems of governance and planning
- Business incubation, new financial models, cost-effectiveness & risks
- Exchange of knowledge & experience, training between urban living labs



Golf Forest Park, Shanghai



Urban green-blue area, Velika Gorika

Combining biodiversity & adaptation in urban park, Aarhus

www.regreen-project.eu

NETWORKNATURE

A new H2020 service for the NBS community far and wide.

Gathers NBS communities, resources, projects, best practices and tools under one roof. The pioneering European platform with a global reach creates opportunities for local, regional and international cooperation to make NBS the new normal.

Consolidate, expand and support a community of practice for NBS across science, business, policy and practice from sub-national to global level, city to regional level;

Upscale the use of NBS across science, business, policy and practice:

- Provide guidance and capacity building
- Creating and operating new European NBS regional hubs
- Networking with practitioners, business, investors and policymakers

Raise awareness

- Communicate the latest findings and news in the NBS field
- Engage existing stakeholders and reaching out to new audiences
- Educate younger generations to become future NBS leaders

EU contribution **2 189 833.75**
Start-End **2020-2023**

networknature.eu

BIODIVERSA

A wide range of NBS projects funded

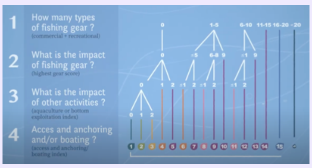
Part of the BiodivERsA joint calls launched since 2008, NBS projects have been funded from NBS of type 1 (based on better conservation) to 2 (better managed for multifunctionality) and 3 (newly designed and managed systems)

SELECTED NBS PROJECTS

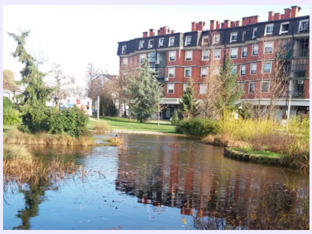
Type 1
- Buffer
- Reservebenfit

Type 2
- Farmland
- Ec21c
- Smallforest
- Vinedivers
- Percebes

Type 3
- Urbes
- Enable
- Urbanmycoserve
- Bioveins



TYPE 1 – BUFFER
Drivers of resilience for Marine Protected Areas ; implications for socio-ecological benefits. Based on >100 case studies of MPAs worldwide
Developed a tool for MPA managers:
www.classifympas.org



TYPE 2 – FarmLand
- Enhance biological control & pollination in agroecosystems through
- innovative landscape planning Identifying the right level of semi-natural habitats to buffer negative effects of climate change

TYPE 3 – URBES and ENABLE
- Evaluate and manage ecosystem services delivered by greening cities (from heat reduction to health benefits)
- Identify and test key features to maximise various service delivery by different urban green spaces

The BiodivERsA project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642420

www.biodiversa.org

ANNEX 5. NBS TASK FORCES IN HORIZON 2020

There is a growing portfolio of Horizon 2020 projects developing evidence base on the role of Nature Based Solutions (NBS) for key policy areas. In order to ensure the EU added value and policy relevance of this coherent portfolio, as well as the maximum social, ecological and innovation impact, the projects are, and will continue to be, 'clustered' around several key topic areas. For the projects, clustering should bring opportunities such as learning from each other, enabling synergies, widening networks, communicating and disseminating results with broader impact, or saving resources around common areas of work. Clustering is about agreeing on some common core parameters and producing common outputs – while valuing project diversity and specificity - to enhance the projects impact, also beyond the projects' partners.

The current clustering exercise is currently organised around 5 Taskforces (TF):

- TF1: Data Management and EU NBS Knowledge Repository;
- TF2: NBS Impact Evaluation Framework;
- TF3: Governance, Business Models and Financial Mechanisms;
- TF4: NBS Communication;
- TF6: Co-creation for NBS.

Taskforces are composed of representatives of the Horizon 2020 NBS projects (who have the lead of technical matters and content), representatives of the Coordinated and Supported Action (CSA) in charge of the NBS Stakeholders platform, representatives from EASME and DG RTD (who provide guidance) and external observers.

16.1. TF1: TASK FORCE ON DATA MANAGEMENT AND KNOWLEDGE REPOSITORY

The EU NBS Knowledge Repository will comprise both evidence for promoting NBS as well as guidelines, tools and methodologies for co-creation, implementation and monitoring of NBS. This one stop shop for Nature Based Solutions will provide added value to achieve better dissemination and visibility, better uptake and mainstreaming and contribution to a lively community of practice.

The overall goal of the task force is to define the approach and implement the solution that will allow to share, search and reuse NBS independently from the project where they have been implemented.

The main expected outcomes of task force 1 are:

- The EU knowledge repository for NBS to which each relevant project will contribute. The repository will be hosted by the open platform OPPLA (https://oppla.eu/)
- A data management plan to ensure contribution of projects as well as to ensure that data are interoperable, open access and comparable

16.2. TF2: TASK FORCE ON NBS IMPACT ASSESSMENT

Objectives:

- A common Impact Evaluation Framework (IEF) to assess the multi-benefits of NBS
- Enhancing the evidence base for NBS and its usability through datasets that cover the multi-benefits of NBS and that can be contrasted
- Link and contribute to other EU and Global work on sustainable urban indicators or other relevant ones (e.g. MAES, SDG 11, Eurostat, Urban Agenda, EEA, EC Smart Cities indicators…)
- Link with the development of a European reference framework on NBS

TF2 key outputs:

- Handbook to guide nature-based solutions impact assessment, including:
  - Guidance on the indicators selection process/co-creation (with studies)
  - Indicators covering all potential impacts/challenges identified for NBS
  - Set of “umbrella indicators” per impact/challenge with at least 1-2 measured by all projects
  - List of additional relevant indicators
  - Guidance on protocols, methodologies, data…
- Collaboration with the EU Urban Agenda Partnership on Land Use Management and NBS, Action 8
  - Common discussions on indicators, collaboration of both initiatives in workshops and events
- Common dissemination and communication activities of the work conducted under TF2
  - Indicators workshop in Slovenia in the context of the project NAIAD

16.3. TF3: TASK FORCE ON GOVERNANCE, BUSINESS MODELS AND FINANCIAL MECHANISMS

The Task Force collaborates mainly on 3 main work streams and cooperation takes place in 3 Working Groups :

- WG1 - Mapping financing mechanisms and business typologies: To work on mapping the landscape of different financing (funding) mechanisms and business typologies that would allow for faster NBS uptake.
- WG2 - Public procurement of NBS: to work together in the area of public procurement and NBS i.e. how should public procurement work in order to favor NBS instead of conventional infrastructure solutions.
- WG3 - Critical elements of NBS business cases: to collaborate and share project experiences in the area of business cases; i.e. What are the essential elements of NBS business case? What has to be taken into account?

Key outputs:

- TF3 is developing joint technical documents and publications in each of the work streams, namely on financing approaches, green public procurement and NBS business models.
- TF3 organised a workshop titled "Nature and the city - insight into nature-based climate adaptation investment" at the 3rd edition of the Covenant of Mayors Investment Forum event organised by DG ENER, DG CLIMA and EASME (Brussels, 18-19 February, 2020).The workshop was framed within the thematic strand focusing on "Future-proof investments – financing climate adaptation". NAIAD, NATURVATION and CONNECTING NATURE H2020 projects delivered a joint session on behalf of the NBS Task Force 3 and presented concrete examples from the projects.
- Contribution to map research gaps in the area of NBS: TF3 prepared a document identifying some key research gaps and barriers to NBS upscaling, with a particular focus on urban NBS and sent it to DG R&I as policy feedback.
- Report on Public Procurement of Urban Nature-based Solutions published in October 2020, as an expert report DG R&I publication.
- Joint Special Issue on Business models for Nature-based Solutions is being developed – it will feature in the Sustainability journal entitled "Nature Based Solutions to Support Climate Change Adaptation and Sustainable Development". The Special Issue will feature articles from various NBS H2020 projects and capture the knowledge developed by them on this topic;

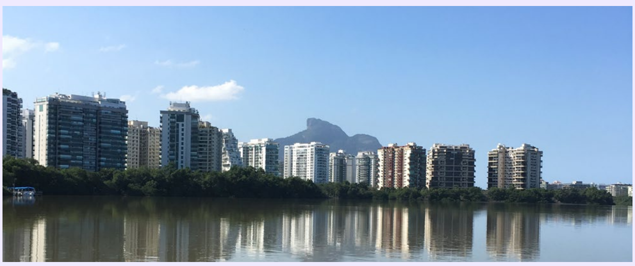
ANNEX 6. THE EU-BRAZIL SECTOR DIALOGUE ON NBS

The European Commission and the Brazilian Ministry of Science, Technology, Innovation and Communication started a dialogue on Nature-based Solutions (NBS) in 2015.

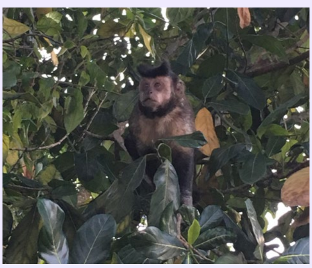
One of the main outcomes is the report Contribution to a Brazilian roadmap on Nature-based Solutions where European and Brazilian experts analyse the occurrence and potential of NBS in Brazil, highlight good practices in the EU, and contribute to the elaboration of a NBS strategy in Brazil. 25 case studies from both sides of the Atlantic illustrate how working with nature can have a positive impact on people's lives. The chosen examples address many challenges: from water management, to ecosystem restoration, urban heat island effect, floods, landslides or coastal erosion.

In particular, the Brazilian case studies span all regions of Brazil and the country's most threatened biomes (the Atlantic Rainforest, the Cerrado, and the Amazon). They display how Brazil's mega-biodiversity could be the solution to a series of issues and provide inspiration to us all. The report concludes that Nature-based Solutions are not only smart investment choices but also a means to enhance quality of life and an opportunity to shift to a new economy and a new lifestyle - more connected to nature.

Recreio green corridor, city of Rio de Janeiro. Copyright: Cecilia Herzog



Recreio green corridor, city of Rio de janeiro. Copyright: Tiago Freitas



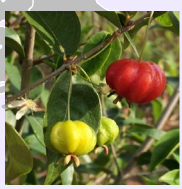
Capuchin monkey, city of Rio de Janeiro. Copyright: Tiago Freitas

Urban nature, city of Sao Paulo. Copyright: Tiago Freitas

Capybara, city of Sao Paulo. Copyright: Tiago Freitas

Native fruits planted in pocket forests and green corridors in Rio de Janeiro and Sao Paulo
Copyright: Tiago Freitas, Ricardo Cardim


Sete-capotes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Grumixama

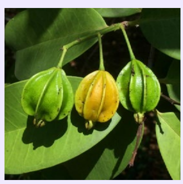

Araçá


Ingá


Uvaia


Cereja-do-Rio-Grande


Cambuci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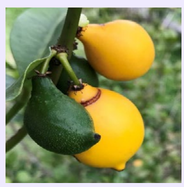
Bacupari

ANNEX 7 : PUBLIC PROCUREMENT OF URBAN NATURE-BASED SOLUTIONS

Addressing barriers to the procurement of urban NBS : case studies and recommendations

Nature-Based Solutions (NBS) can be a powerful tool for cities dealing with the contemporary sustainability challenges including degradation of natural capital and ecosystem services, vulnerability to climate change and natural disasters, as well as corresponding health and wellbeing issues. NBS have potential to boost local economies and create business opportunities. However, many public authorities still report difficulties in using public procurement to implement NBS projects. This report provides an overview of the major challenges facing NBS procurers in the EU, along with case studies of success in addressing those barriers across nine European cities. The findings may help other public authorities adapt their procurement processes to procure NBS more effectively.

The report is aimed at public procurers, policymakers, city planners, and public authorities interested in and/or already pursuing NBS projects. Drawing from case studies from across the EU, it explores challenges and solutions for procuring successful NBS projects. Whilst the focus is given to projects undertaken in an urban context, several principles of NBS procurement highlighted in the report may be of relevance to practitioners operating in rural areas. Those findings will be relevant to the NBS community including but not limited to H2020 project representatives, academia, and the private sector stakeholders. The analysis has been set out in a reader-friendly manner to ensure it is also accessible to a general audience with limited pre-existing knowledge of NBS and/or public procurement.

Link

ANNEX 8 : EVALUATING THE IMPACT OF NATURE-BASED SOLUTIONS: A HANDBOOK FOR PRACTITIONERS

The Handbook aims to provide decision-makers with a comprehensive NBS impact assessment framework, and a robust set of indicators and methodologies to assess impacts of nature-based solutions across 12 societal challenge areas: Climate Resilience; Water Management; Natural and Climate Hazards; Green Space Management; Biodiversity; Air Quality; Place Regeneration; Knowledge and Social Capacity Building for Sustainable Urban Transformation; Participatory Planning and Governance; Social Justice and Social Cohesion; Health and Well-being; New Economic Opportunities and Green Jobs.

Indicators have been developed collaboratively by representatives of 17 individual EU-funded NBS projects and collaborating institutions such as the EEA and JRC, as part of the European Taskforce for NBS Impact Assessment, with the four-fold objective of: serving as a reference for relevant EU policies and activities; orient urban practitioners in developing robust impact evaluation frameworks for nature-based solutions at different scales; expand upon the pioneering work of the EKLIPSE framework by providing a comprehensive set of indicators and methodologies; and build the European evidence base regarding NBS impacts. They reflect the state of the art in current scientific research on impacts of nature-based solutions and valid and standardized methods of assessment, as well as the state of play in urban implementation of evaluation frameworks.

ISBN 978-92-76-22961-2; DOI 10.2777/2498

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This document summarises outcomes from the EC individual expert reports delivered through its ‘Valorisation of NBS Projects’ initiative. EU research and innovation projects were scanned for results pertaining to key areas such as biodiversity, climate change mitigation and adaptation (including flooding), water quality, air quality and microclimate, sustainable communities, innovative governance and business models, and market challenges and solutions. Evidence from the reviewed projects (and the EC’s NBS policy topic area) is framed within knowledge from the wider literature, to give as full a picture as possible about the state of the art. Contextualised information is provided on policy developments, research results and key lessons. The resulting evidence base includes figures and monetary values showing the relative cost-effectiveness of NBS, and exploring how they support policy implementation. Policy recommendations and knowledge gaps are also highlighted to support the strengthening of strategies and practical action for the uptake of NBS, to deliver targeted and efficient interventions to help solve societal challenges in Europe and beyond.

Studies and reports

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