RECONECT

NBS for hydro-meteorological risk reduction: review of existing knowledge base, practices and policies

Deliverable D1.3

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Abstract	The purpose of this report is to establish state-of-the-art for the existing knowledge and practice for NBS in Europe and beyond. The focus is on practices for implementation, policies that promotes or hinders the implementation of NBS practices as well as the scientific evidence on the benefits and disadvantages of NBS implementation. A missing link to implementation of NBS, especially outside of urban areas, remains to be established, including suitable financing mechanisms as well as a more comprehensive framework for the analysis of potential for NBS, considering both benefits and disadvantages.
Keywords	Nature-based solutions; NBS; NBS state-of-the-art; NBS knowledge base; NBS construction and implementation practice; Policy frameworks for NBS; Lead user method for NBS

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Executive Summary

This report describes the existing knowledge, practices and policies regarding Nature-Based Solutions (NBS), with focus on large-scale solutions in Europe and beyond. The focus is on practices for implementation, policies that promotes or hinders the implementation of NBS practices as well as the scientific evidence on the benefits and limitations of NBS implementation. This report acts as a baseline for scientific state-of-the-art and policies regarding NBS implementation within and beyond RECONECT. Furthermore, the tools developed and identified to help in future gap analysis are relevant for all future NBS implementation as a means to make best use of the existing knowledge on NBS. This report is intended to address two audiences: partners within the RECONECT project that are implementing large-scale NBS where it should act as the common knowledge base with rich references to existing implementations of NBS. The other key audience is researchers and practitioners beyond RECONECT who are engaged with implementation and assessment of NBS across all scales.

State-of-the-art of NBS implementation shows that experiences with NBS are widespread and that implementation happens globally. However, these are often not explicitly referred to as NBS, but are referred to under a vast amount of terms specific for regions and/or managing origin. An overview of NBS relevant terms are provided as part of this report to help readers.

The state-of-the-art analysis further shows that there exist a multitude of terms and indicators to describe NBS behaviour, of which many seems to be overlapping. This indicate that a stable regime for NBS have not been established yet, despite significant EU initiatives aimed at mainstreaming NBS, such as OPPLA. The lack of maturity is even more pronounced when considering large-scale implementation in non-urban regions where very few relevant projects are termed directly as NBS.

EU level policies is most often mentioned in implemented NBS projects followed by local level policies and plans. Regional and national policies are very seldom mentioned. A cluster analysis showed that local policies seem to be more relevant for reducing the risk from droughts and extreme temperature and for addressing the challenges of climate resilience, green space management, air quality, urban regeneration, participatory planning, social justice and public health. Contrarily, EU policies seem to be more relevant for mitigating risks stemming from flood events, storms and sea level rise and for addressing challenges such as water management, coastal resilience and disaster risk reduction.

Based on the state-of-the-art and policy analyses, an NBS synthesis geodatabase has been developed for RECONECT. It describes the existing knowledge and practice of NBS based on synthesis of knowledge from a number of existing web-based platforms. The synthesis geodatabase enables better gap analyses and allows users to identify or search for experience that may help in overcomming these gaps. Further the Lead User Analysis has been identified as a platform for communicating solutions to these gaps. As such the Lead User Method and the synthesis geodatabase is a means to ensure rapid uptake of innovative solutions to hydro-meteorological problems.

A missing link to implementation of NBS, especially outside of urban areas, remains to establish suitable financing mechanisms as well as a more comprehensive framework for the analysis of potentials for NBS, considering both benefits and limitations. This is key to establishing a technological and political regime where the uptake of NBS is promoted to enhance conditions for both water, nature, and people, in light of the local context, and balancing any conflicts between each of the objectives.

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1 Introduction

1.1 Background

Nature Based Solutions (NBS) are increasingly being acknowledged as the key to managing natural hydrological extremes in the future where climatic changes will increase the size and rate of occurrence for both droughts and floods. Already now, NBS is being implemented as functional responses to extreme, damage-causing events; e.g. the Dutch Room for the River project (Rijke et al., 2012) as a response to the Rhine River floods in 1993 and 1995 (Engel, 1997), the Copenhagen Cloudburst Management Plan as a direct response to the major pluvial floods of Copenhagen in 2010 and 2011 (City of Copenhagen, 2012) and the Dublin Climate Change Action Plans (Dublin City Council, 2019) that were created as a response to recurring severe pluvial flooding events in 2002, 2008, 2009 and 2011 (Dublin City Council et al., 2017).

Implementation of Nature-Based Solutions (NBS) for hydro-meteorological risk reduction offers the possibility to break away from traditional practices and enable to reconnect our land management practices and developments with nature in order to achieve multiple benefits to services and functions of ecosystems. According to Olsen and Bishop (2009a) and van der Nat et al. (2016), such measures are potentially more cost-effective and adaptable than traditional hard engineering measures. However, cost-effective design and implementation of NBS is only part of the answer. Of equal importance is the ability to effectively place them in diverse local and cultural contexts and integrate them into broader land and risk management strategies. It is therefore of crucial importance to understand the complexity of each case. This promotes designs that minimise social and economic losses as well as environmental impacts, increase resilience to hydro-meteorological events while ensuring business models and financial viability. Good examples of large-scale NBS for hydro-meteorological risk reduction that can act as reference for replication and upscaling is currently lacking and there is a clear need to enhance their evidence base through demonstration within the European reference framework.

RECONECT is an interdisciplinary international project that aims to contribute to the EU reference framework 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 risks with local and regional development objectives in a sustainable way. Further, RECONECT focus the quantification of impacts under three headings: Water, Nature and People, to emphasize that all three categories has to be deliberately addressed when implementing NBS.

In order to contribute effectively to the EU reference framework on NBS and to generate higher impacts across Europe, RECONECT draws upon a number of Demonstrator and Collaborator Sites. These have been carefully selected to cover a range of local criteria including (1) climatic and geographic conditions; (2) type of hydro-meteorological events (floods, storm surges, droughts, landslides) and (3) vulnerability to these events. Additional to these criteria, the potential for collaboration and upscaling has also played a role in the selection process.

In order to capitalise on the existing knowledge and experiences on NBS within the RECONECT Consortium and initiate the knowledge sharing and upscaling process already in an early project stages, RECONECT base its demonstration activities on two types of Demonstrators (A and B), which are at different stages in the NBS co-creation process. They further share this knowledge and experience with the Collaborators.

In Demonstrators Type A the large-scale NBS will include the full co-creation (i.e., co-assessment, co-design, co-implementation, co-monitoring and co-evaluation) and validation process during the project lifetime either by requesting co-funding from the EC and/or by deploying their own funds and resources.

The Demonstrators Type B cases have a considerable track record in implementing large-scale NBS in sensitive natural and rural areas (e.g. mountainous and coastal areas) with high local/national/international visibility. In order to capitalise on their experiences on already implemented NBS, RECONECT will demonstrate their NBS by co-monitoring, co-evaluating and validating their multiple benefits.

Collaborators, both with the EU and around the world, are inspired and advised by RECONECT Demonstrators to produce prefeasibility studies for implementation of NBS based on the experience generated in RECONECT. The prefeasibility studies will involve assessment of the following: potential sites for NBS implementation, applicable types of large-scale NBS, their potential benefits/co-benefits and the potential for mainstreaming NBS in land use planning and policy framing.

Both, Demonstrators and Collaborators form the RECONECT NBS network of cases. The geographic spread of the individual cases is presented in Figure 1.

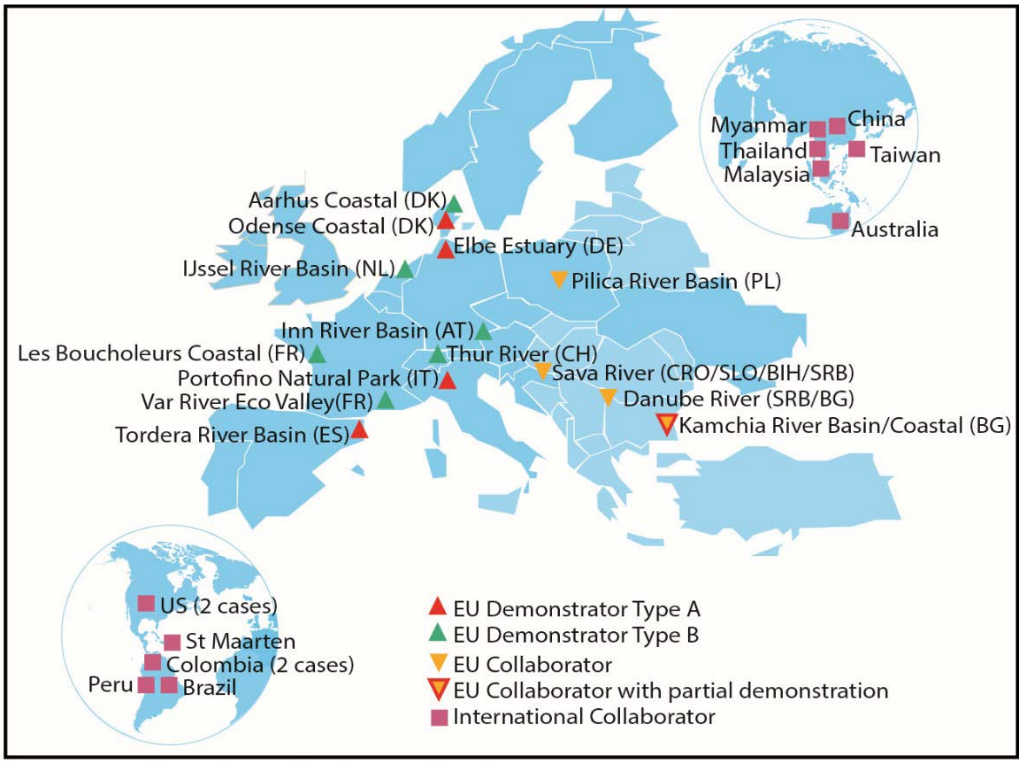


Figure 1 ***RECONECT Network of cases.***

In order to demonstrate and upscale the NBS, in RECONECT a holistic ecosystem-based approach is developed and deployed, which takes into account the interrelatedness and interdependencies within the sociotechnical system (e.g., market demand dynamics, land management actions, policy development, etc.) and the hydro-meteorological events such as floods, droughts or landslides taking into account the local contexts in each of the Demonstrators and Collaborators cases. The demonstrated NBS are to be evaluated within the evaluation framework that is structured over the three main groups of challenges being water, nature and people (see Figure 2).

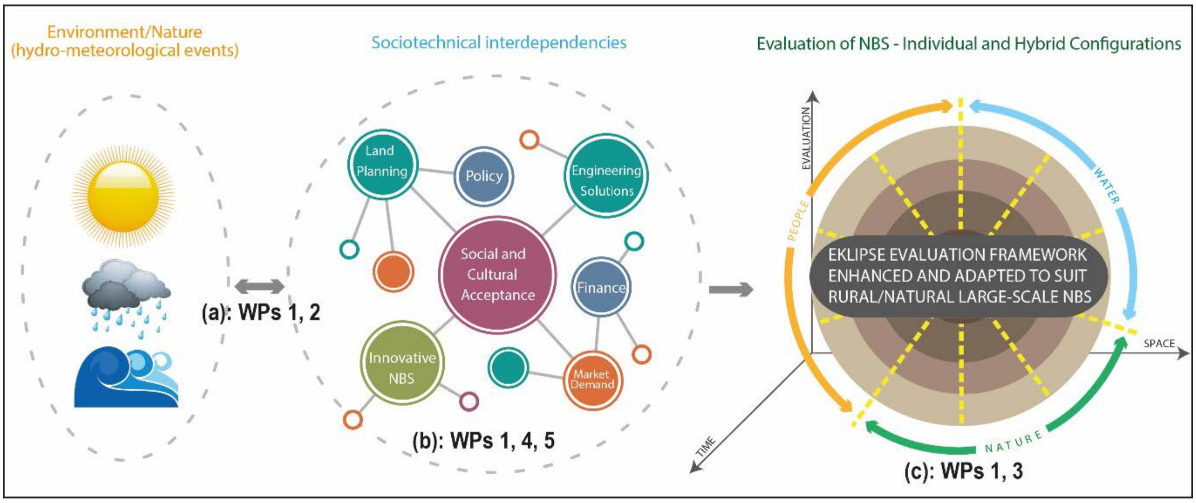


Figure 2 RECONECT holistic ecosystem-based framework with the evaluation framework structured over the three main categories of challenges: water, nature and people

RECONECT WP1 on "Framing science, policy and practice" sets the scope of RECONECT and delivers the frameworks, state-of-the-art analyses, and enhancements of the technologies and tools to the RECONECT Network of Cases. The emerging relevant enhancements and developments in the field of NBS are analysed and addressed in order to make use of them for the demonstration and upscaling within RECONECT. In WP1 the RECONECT ecosystem-based approach is developed with the indication on how to integrate the evaluation framework are outlined (delivered in report D1.1) (refer to Figure 2).

So far, frameworks for the management of hydrological risk through NBS have primarily focused on the urban setting. In Europe the topic of NBS or its sister concepts (such as SUDSs, LIDS, Eco Engineering), has been addressed through a number of large projects (e.g. DESSIN, Nature4Cities, Naturvation, NAIAD, ThinkNature) and synthesized in the EKLIPSE framework (Raymond et al., 2017a). In China, the sponge city strategy reflects the same urban focus (Jia et al., 2017; Randall et al., 2019) and similar implementations have been seen in the USA (Jones et al., 2012; U.S. Environmental Protection Agency, 2017) and Australia (Melbourne Water, 2017; Radhakrishnan et al., 2019) even though the term NBS is fairly new (Nature Editorial, 2017) and mostly used in Europe. Large-scale NBS best practices and measures are not new concepts, but have been used under different names in the past (e.g. Eco engineering). Even so, there is a need to summarise and analyse the existing knowledge and experience on large-scale NBS and bring them beyond the urban setting and relate them to implementation in rural and natural areas.

1.1 Objectives and Structure of This Report

The objective of this report is to contribute to the establishment of the state-of-the-art of large-scale NBS with a focus beyond the urban setting including rural and natural areas, and further strengthen the reference to relevant policies and regulations.

The remainder of this report is structured over the following main subtopics:

- Chapter 2: Definition of NBS and especially large-scale NBS for hydro-meteorological risk reduction based on a survey of existing concepts. Establishment of state-of-the-art regarding NBS implementation both in the rural and natural as well as in the urban setting. The implementation practices are presented in relation to how they have addressed the

three main categories of challenges being **water, nature and people** as introduced in section 1.1
- Chapter 3: Analyzing and relating relevant policy frameworks to NBS. Including an analysis the link between the science-policy-practice i.e. in which way these influence each other in the implementation of NBS
- Chapter 4: Identification of repositories of sample applications (e.g. key databases or other sources of information) that can be relevant for the RECONECT cases by delivering state-of-the-art NBS cases and practical aspects of NBS implementation and description of the development of a database of NBS synthesizing this knowledge for use in the future work in RECONECT.
- Chapter 5: Presentation of the lead user method as a methodology to pursue novel innovations related to NBS not necessarily reported in the databases and for identifying the potential for enhancements of NBS related technologies, tools and methods
- Chapter 6: A brief outlook reflecting on the link between the science policy and practice and outlook outlining the identified gaps and challenges in the implementation of NBS

The structure of the report is further depicted in Figure 3.

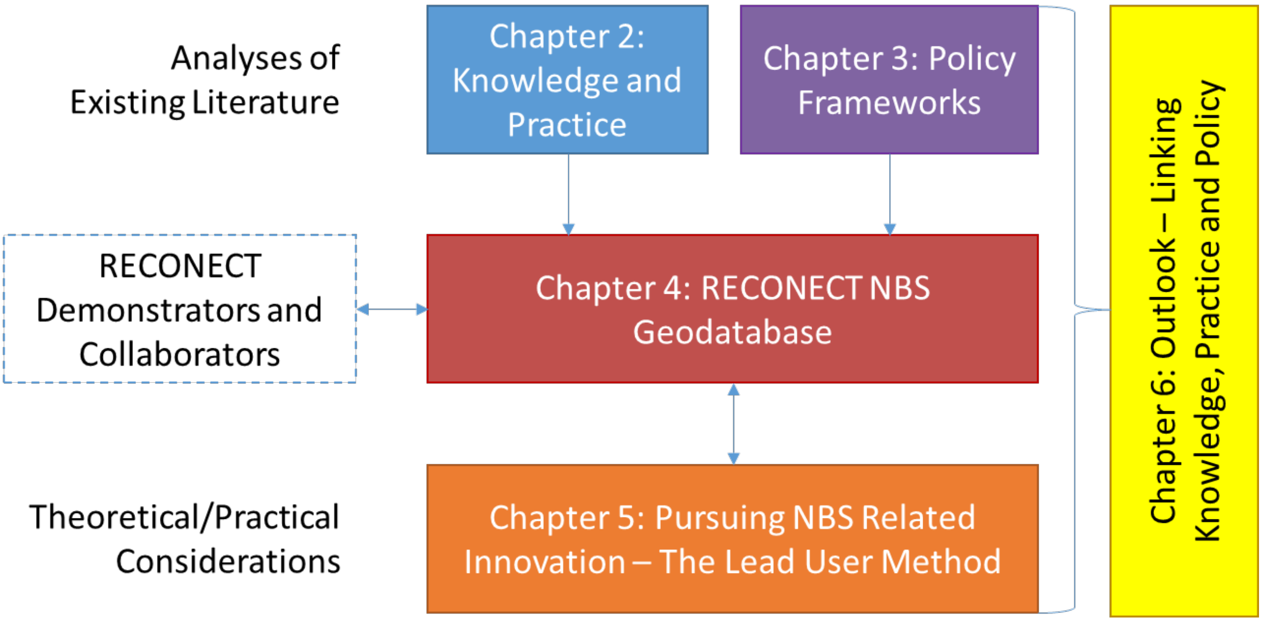


Figure 3 Structure of this report with the interaction between chapters and to the RECONECT Demonstrators and Collaborators illustrated with arrows.

This report is intended to address two types of audiences**.**
- Partners within the RECONECT project that are implementing NBS for hydro-meteorological risk reduction.
- Researchers and practitioners beyond RECONECT who are engaged with various aspects related to the realization of NBS.

For both audiences this report is intended as an inspiration catalogue where the main services provided by NBS is linked to good practical examples that illustrate how this works in practice and provide insight into the additional benefits that NBS can provide when implemented with a given intention (see chapter 2). At the policy level this report provide a structured overview of which, primarily EU, policies that are relevant when implementing NBS with different purposes. This can be used by practitioners, as a basis for seeking out relevant policies that offer support when NBS is implemented to solve a given problem (see chapter 3). Further, this report provide a practical geodatabase to the partners in RECONECT that synthesises knowledge from a range of existing NBS repositories to efficiently support knowledge gathering on NBS (see chapter 4). Finally, this geodatabase is to be further populated by so far under explored NBS technologies that are uncovered through the Lead User Method in RECONECT (as described in chapter 5). The outlook provided is intended to inspire the scope of work within RECONECT and beyond (see chapter 6).

1.2 Links to Other Deliverables in RECONECT

The following activities and tasks within RECONECT are relevant for this deliverable:

D1.3 receives input from the following RECONECT Deliverables:

- D1.2: Social innovation approach. In particular the development of an up-scaling strategy based on demand-and-supply analysis to assess the needs of the demonstrators and collaborators.
- D2.3: Report describing scope of works for Demonstrators, and
- D2.5: Preparatory actions of Demonstrators. For both reports the input is especially the practical limitations in choice of NBS.

Deliverable D1.3 will be used as direct input to the following RECONECT Deliverables:

- D1.7: That describes the beyond-state-of-the-art framework key to RECONECT. Here the results of this report will act as the state-of-the-art baseline for comparison.
- D1.4: That unfolds the innovation potential for NBS within RECONECT. Here the Lead User Method will be concretized further in relation to the Demonstrators.
- D1.5: That provides a deeper analysis of the tools and methods relevant for planning and design of large-scale NBS. Here the results of this report will act as the state-of-the-art baseline for comparison.
- D4.6: The assessment of barriers (regulatory, economic and social) for establishing and upscaling of NBS. Here the policy analysis will play a key role in establishing the regulatory barriers.

2 Overview of Knowledge and Practice for NBS

2.1 Introduction

This chapter dives into the definition of NBS and the historic and geographical context in which the term was conceived; hereby touching upon its sister concepts and the ongoing discussions about overlap between these.

The main part of the chapter goes on discussing the main services delivered by NBS with respect to water management, nature conservation and people benefits, connecting concepts to concrete projects that are seen as prime practical examples, before touching upon the monitoring frameworks that has been proposed and implemented so far to best measure these services.

The diversity and complexity of conceiving and implementing NBS is discussed and the need for and opportunities of adapting to local contexts is discussed while also demonstrating that the concept is reaching a mature level. As such the chapter can both serve as a starting point with respect to showcasing which services that should at least be considered, whenever NBS is implemented, but also to highlight the endless opportunities for upscaling by focussing on all the potential services NBS can deliver, including reduction of impacts of hydro-meteorological extremes.

2.2 The Term NBS and Its Relation to Its Sister Concepts

In recent years, holistic and dynamic approaches, such as nature based solutions, natural solutions, ecosystem-based adaptation, ecological engineering, green and blue infrastructure, biomimicry, ecosystem-based disaster risk reduction and natural water retention measures, are emerging within eco-urbanism, especially in North America and Western Europe (Eggermont et al., 2015; Scott and Lennon, 2016).

The reason behind a plethora of terminology is that it arose during different time periods and within different systems. According to (Kabisch et al., 2016), the concepts are complementary and may have considerable overlap, as they all focus on developing systemic approaches for addressing impending pressures and risks, and are suitable for use also in a nonurban context.

The term **nature based solutions (NBS)** was first used in the late 2000s in the context of finding new solutions for climate change adaptation and mitigation, which incorporate the dimensions of biodiversity protection and sustainable living (Eggermont et al., 2015). Only recently, it was put forward by practitioners, most notably the International Union for Conservation of Nature (IUCN) reflecting the need for full integration of the ecological dimension into traditional planning concerns (Scott and Lennon, 2016). It is a broad open nature concept that includes solutions of varying scales and functions (Eggermont et al., 2015; Hansen and Pauleit, 2014).

There are several definitions used in the international scientific community with the two most prominent definitions from the International Union for Conservation of Nature (IUCN) and the European Commission.

The IUCN has proposed a definition of NBS as:

> *"Actions to protect, sustainably manage and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits"*
>
> (Cohen-Shacham et al., 2016).

The European Commission defines NBS as follows:

> *"… 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."*

(European Commission, 2020).

Eggermont et al. (2015) proposed a typology characterising NBS into three types:

- NBS that address a better use of natural or protected ecosystems (no or minimal intervention), which fits well with how the IUCN frames NBS,
- NBS for sustainability and multi-functionality of managed ecosystems, and
- NBS for the design and management of new ecosystems, which is more representative of the definition given by the European Commission.

NBS is a collective term for innovative solutions to solve different types of societal and environmental challenges, based on natural processes and ecosystems. Therefore, it is considered an "umbrella concept" covering a range of different ecosystem-related approaches and linked concepts that provides an integrated way to look at different issues simultaneously (Cohen-Shacham et al., 2016; Nesshöver et al., 2017).

NBS are envisaged to enhance climate change resilience and mitigation, while being more efficient than traditional measures (Brudler et al., 2016; Sørup et al., 2019). European Environment Agency (2015) emphasizes that NBS address specific demands and challenges in a sustainable manner, while simultaneously generating additional environmental, economic, and social benefits. NBS can prove to be more cost-effective and adaptable, demand less raw material and improve ecosystem functioning, compared to traditional engineering measures (Brudler et al., 2016; Olsen and Bishop, 2009b; van der Nat et al., 2016).

Due to the diverse policy origins, NBS terminology has evolved in the literature to emphasise different aspects of natural processes or functions. In this regard, nine different terms are commonly used in the scientific literature in the context of hydro-meteorological risk reduction: low-impact developments (LIDs), best management practices (BMPs), water-sensitive urban design (WSUD), sustainable drainage systems (SuDS), green infrastructure (GI), blue–green infrastructure (BGI), ecosystem-based adaptation (EbA) and ecosystem-based disaster risk reduction (Eco-DRR). The timeline of the NBS related terms in relation to their appearance in the literature is shown in Figure 4.

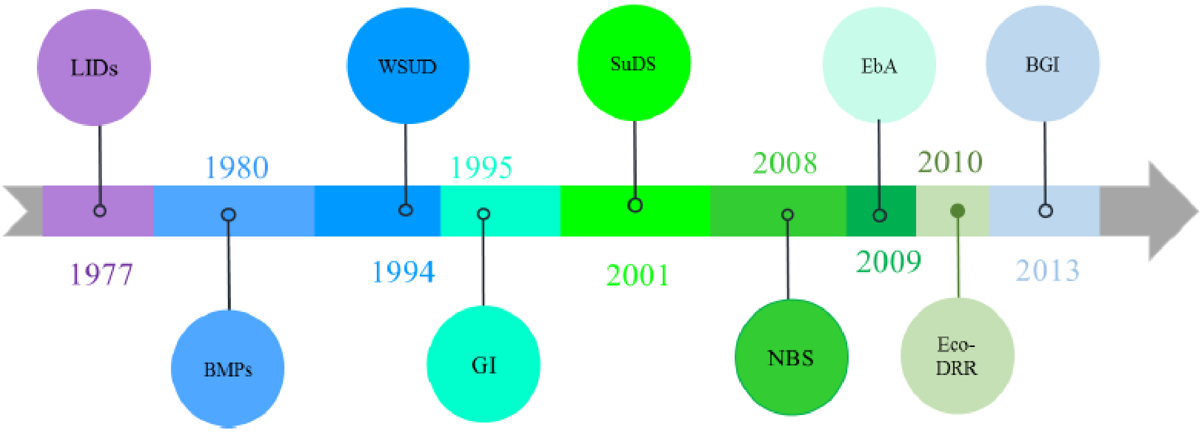


Figure 4 Timeline of the NBS related terms in relation to their appearance in the literature (Ruangpan et al., 2020)

The commonalities between a NBS and its sister concepts are that they take participatory, holistic, integrated approaches, using nature to enhance adaptive capacity, reduce hydro-meteorological risk, increase resilience, improve water quality, increase the opportunities for recreation, improve human well-being and health, enhance vegetation growth, and connect habitat and biodiversity. More information on the history, scope, application and underlying principle of terms of SuDs, LIDs, BMPs, WSUD and GI can be found in Fletcher et al. (2015), while the relationship between a NBS, GI/BGI and EbA is described in detail by Nesshöver et al. (2017). Although all terms are based on a common idea, which is embedded in the umbrella concept of NBS, differences in definition reflect their historical perspectives and knowledge base that were relevant at the time of the research (Fletcher et al., 2015).

The distinguishing characteristic between a NBS and its sister concepts is how they address social, economic and environmental challenges (Faivre et al., 2018). Some terms such as SuDs, LIDs and WSUD refer to NBS that specifically address stormwater management. They use the landscape feature to transform the linear approach of conventional stormwater management into a more cyclic approach where drainage, water supply and ecosystems are treated as part of the same system, mimicking more natural water flows (Liu and Jensen, 2018). GI and BGI focus more on technology-based infrastructures by applying natural alternatives (Nesshöver et al., 2017) for solving a specific activity (i.e. urban planning or stormwater). EbA looks at long-term changes within the conservation of biodiversity, ecosystem services and climate change, while Eco-DRR is more focused on immediate and medium-term impacts from the risk of weather, climate and non-climate-related hazards. EbA is often seen as a subset of NBS that is explicitly concerned with climate change adaptation through the use of nature (Kabisch et al., 2016).

Eggermont et al. (2015) point out, that structures which are designed for one function, e.g. rain gardens for managing stormwater run-off, but do not regard biodiversity enhancement and other ecosystem services, should not be considered NBS. They further emphasize that a selection of clone species or a very few plant species may lead to poor resistance and resilience to future extreme events, increased management costs and risk of biological invasions, hence largely missing out on the sustainability objectives, but also on overall effectiveness.

The above mentioned concepts have their origins and are spread at different locations around the world with the key ones given in Figure 5.

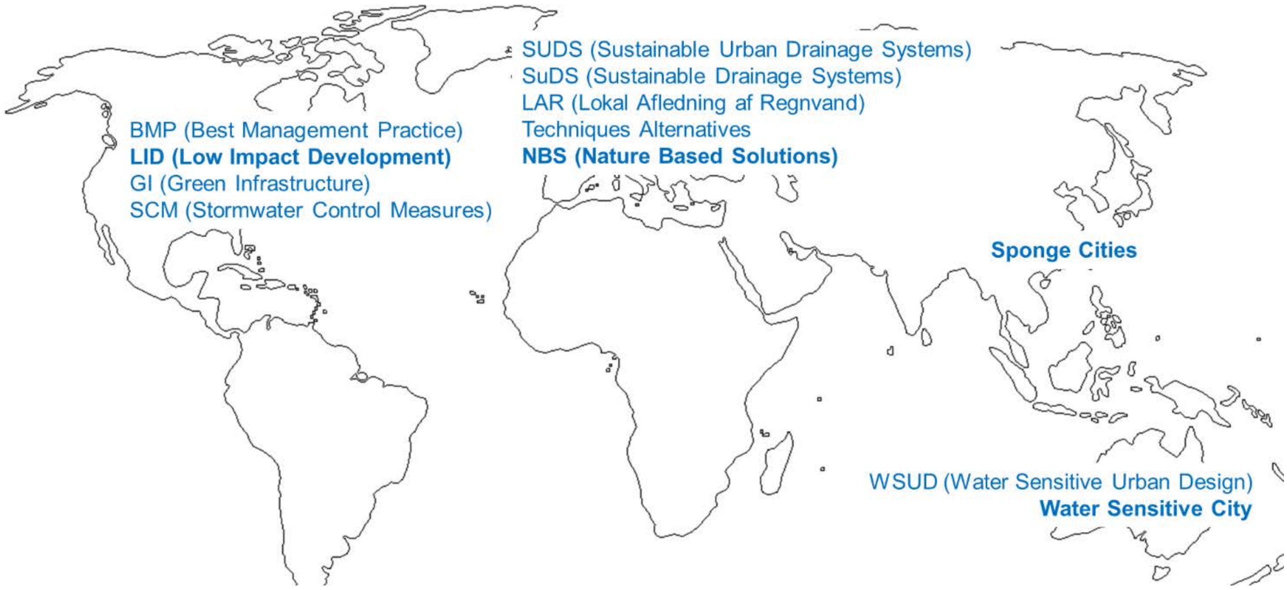


Figure 5 Worldwide terminology related to the implementation of NBS. Illustration by Sara Lerer based on (Fletcher et al., 2015; Lerer et al., 2015).

From the above presented discussion, it can be concluded that EbA, Eco-DRR and GI–BGI provide more specific solutions to more specific issues. One key distinction is that unlike the sister concepts, NBS is more open to different interpretations, which can be useful in encouraging stakeholders to take part in the discussion. Moreover, features of NBS provide an alternative to working with existing measures or grey infrastructures. Therefore, it is important to note that very often a combination between natural and traditional engineering solutions (also known as "hybrid" solutions) is likely to produce more effective results than any of these measures alone, especially when their co-benefits are taken into consideration (Alves et al., 2019; Sørup et al., 2019)). An important advancement in the science and practice of NBS is given by the EKLIPSE Expert Working Group, which developed the first version of a multi-dimensional impact evaluation framework to support planning and evaluation of NBS projects (Raymond et al., 2017a). RECONECT builds upon the EKLIPSE Framework and enhance it to fit to the needs and requirements for the evaluation of the large-scale NBS projects beyond the urban setting.

Also, the geographic distribution of the NBS and its sister concepts as presented in Figure 5 indicates that the complete picture of their implementation is still missing. The key reason for this is that only Europe and Australia have been focused on documenting and reporting them into databases. Despite the lack of reporting, it is evident that NBS implementation in e.g. China and the USA is widespread (Jia et al., 2017; Liu and Jensen, 2018; U.S. Environmental Protection Agency, 2017) and that implementation exists all over the world (UN Environment – DHI et al., 2018; UN Water, 2018). RECONECT addressed this scattered way of reporting of NBS and their low visibility in the international context by adopting and enhancing the Lead User Method as described in Chapter 5 in detail.

2.3 State-of-the-Art of Large-Scale NBS Implementation

Large-scale water balances, water fluxes, water management and ecosystem services are affected by future changes such as climate change, land use changes, water use changes and population growth. To address such challenges, large scale NBS are implemented. Generally, a large-scale NBS combines different NBS elements within a larger system to achieve better long-term strategies and performance.

Generally, this review focus on NBS elements that can be combined into large-scale NBS. This choice reflect that documented NBS solutions for large parts cover the urban setting and a much smaller implementation scale than what is aimed for in RECONECT. Examples of elements that may be combined into one coherent NBS implementation is shown in Figure 6, extracted from the comprehensive Room for fhe River project. Figures Figure 7 and Figure 8 highlight that such elements may indeed themselves be of considerable size. All of these examples are demonstrators of the RECONECT project. In large-scale NBS often several elements are needed, and often also elements that are not explicitly NBS elements, but nevertheless are critical for the overall functionality of the solution. When using such “grey” elements the large scale NBS is sometimes referred to as hybrid solutions.

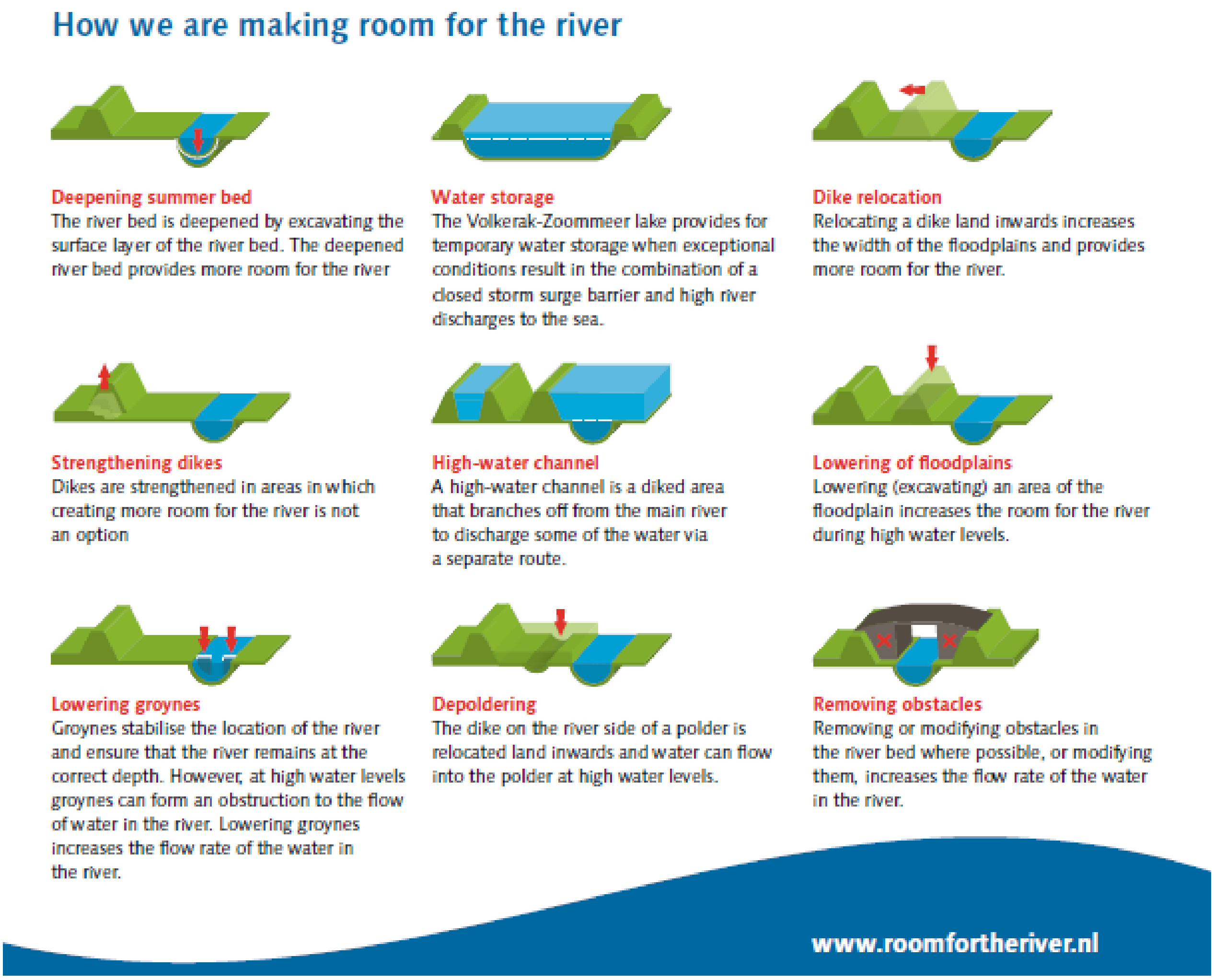


Figure 6 An overview of the ”Room for the River” strategies and measures (www.roomfortheriver.nl).

Figure 7 The artificial lake and wetland Egå Engsø surrounded by grazed meadows looking southeast. The bay of Aarhus in the background.

Figure 8 Thur river at Niederneunforn. Left: before restoration in 2002. Right: after restoration in 2008. (© BHAteam, Frauenfeld).

The examples mentioned above show that NBS are indeed suitable for mitigating hydro meteorological risks as well as the co-benefits to nature and people. This state of the art review has been structured in accordance with these three main dimensions in accordance with the overall structure of the RECONECT project (See section 1.1) noting that in general the NBS implementation should be better than the baseline for all three main dimensions. Hence, when we discuss NBS designed for water management (in Section 2.3.1) the aim is not to present NBS that are only relevant for water management, but merely discuss what water management relevant issues that can be managed through NBS. As, such the same examples and solutions can appear multiple times as they are good examples providing solutions within all three dimensions. This review is based on the analysis in which way and to which extent the existing practices of NBS have addressed those dimensions.

2.3.1 NBS Designed for Water Management

Overall, hydro-meteorological extremes pose challenges that water is either available in very large or very scarce quantities, creating critical situations that need management (Fratini et al., 2012; Sørup et al., 2016). The solutions put in place on this background should then, on an everyday basis, play a positive role and help improve water quality locally while at the same time mitigate the effects of extreme weather events. In the following sections, we summarize state-of-the-art with respect to management of water quantity and quality through NBS.

2.3.1.1 Managing Water Quantity through NBS

Large rivers still today serve as important transport infrastructure and therefore, many large cities are situated along the banks of large rivers. This exposes them to fluvial flood risk, as the rivers drain very large catchments and good practice in mitigation of this risk is through NBS. Room for the River (Rijke et al., 2012) in the Netherlands is a great example of how giving more space to the river increases the discharge capacity during high water levels.. Some other NBS-based pluvial flood mitigation projects that can be mentioned include: the Mekong Delta (Asian Development Bank, 2016), the Emscher river renaturation project in Germany (Gerner et al., 2018) and the reservation of the grassland along the Elbe river outside of urban areas *(Elbwiesen)* for controlled flooding in the center of Dresden, Germany (Dresden City, 2015).

The mechanisms behind coastal flooding are very different from those leading to pluvial and fluvial flooding. Coastal flooding is driven by sea surges and local hydraulic conditions can have great influence on what causes flooding conditions from sea surges (Hennequin et al., 2018). The Netherlands has a long tradition of coastal protection through NBS (Temmerman et al., 2013; Van Wesenbeeck et al., 2014) and Denmark as well where the natural coasts are seen as the greatest national nature asset (Faragò et al., 2018). But examples that focus less on flood protection and more on water quality and ecology also exist; e.g. Moreton Bay, Australia (Arthington et al., 2019), The Venice lagoon, Italy (Bendoricchio et al., 2017; Sfriso, 2018) and Gyldensteen Beach, Denmark (Faragò et al., 2018; Thorsen et al., 2016). In river estuaries, fluvial and coastal flooding can coincide and potentially cause more severe combined situations (Pedersen et al., 2012; Temmerman et al., 2013).

Droughts and landslides are risks strongly associated with human use of land, as agricultural land has poorer water holding capacity in dry situations and at the same time poorer conditions for retaining soil in flooding situations. Hence, NBS like wetlands will increase an area's resilience towards drought, and solutions including more permanent vegetation (like forests) will greatly decrease the risk of erosion and landslides (UN Environment – DHI et al., 2018).

2.3.1.2 Managing Water Quality through NBS

Water is most often not pure but acts both as a source and sink for compounds that are considered pollutants, and hence water quality is a function of upstream processes in the catchment. Urban surfaces are known to generate polluted runoff (Brudler et al., 2019) and the same applies to agricultural soils (Hart et al., 2004; U.S. Environmental Protection Agency, 2015), and all stormwater runoff can potentially contain substances that can pose a risk to the receiving waters. NBS are potential solutions to reduce runoff pollutants if designed properly (Masi et al., 2017; Sage et al., 2015; Scholes et al., 2008; Vezzaro et al., 2009). sØnæs in Viborg, Denmark, is a prime example of an NBS solution that acts both as a pluvial protection measure and at the same time is designed to increase the water quality on an everyday basis (carlberg/christensen, 2015).

Generally, NBS for water quality management are widespread with constructed wetlands being the dominant technology (Li et al., 2007; Masi et al., 2017; Silva et al., 2010; Thomas et al., 2016). Further, combinations of ponds and swales are solutions often seen at the neighbourhood scale for both peak flow reduction and water quality enhancement (Åstebøl et al., 2004). In Australia, constructed wetlands are now widespread to prevent pollution from reaching receiving waters (Melbourne Water, 2017) even though the over-utilization of wetlands has also increased flood risk locally (Löwe et al., 2018; Radhakrishnan et al., 2019).

2.3.1.3 Conclusions and Remaining Gaps

The hydrological drivers and local climatic and catchment conditions can all be limiting factors for implementation of NBS and make mainstreaming difficult. Some hydrological processes like the potential for evapotranspiration will wary throughout the year and will be somewhat correlated to the time when availability of infiltration capacity is also expected. Hence, hydro-climatic runoff extremes has to happen in the catchment at the time of year where evapotranspiration and infiltration can be increased (typically summer and some of spring and autumn) if these processes are expected to be part of the solution. Places where winter extremes is the dominating problem these processes might only have limited effect and the solution space for implementation of NBS is greatly limited.

Each element of an NBS can typically only handle a small catchment, but many small systems can be combined to serve a large catchment with a large number of small decentralized NBS elements. Here, short and frequent events will generally be handled well, whereas longer events or rare extreme events with substantial volume might experience saturation problems where infiltration and evapotranspiration cannot be increased further, leading to substantial runoff of surplus water.

At the small scale, NBS is generally well understood from the urban setting. At larger scales interaction between NBS elements will play a larger role and the systems will at the same time experience the largest pressure from long voluminous events rather than short intense events. The antecedent conditions prior to any hazard occurring is hence much more complex to describe, making upscaling difficult.

2.3.2 NBS Designed for Nature

To sharpen the state-of-the-art of NBS impact on nature the following sections are framed by the concepts of habitat structure and biodiversity. Habitat structure tackles issues related to the quantity (area) and quality (e.g. provision/heterogeneity and distribution/connectivity) of natural areas. This recognizes the role of the physical structure of habitat (hydromorphology; see e.g. (O'Hare et al., 2015) as well as land use type (either adjacent to nature or to be reclaimed for nature purposes within NBS settings), which will directly influence the ecological state. Implementation of NBS tackles issues related to the general decreasing biodiversity (e.g. abundance and type of species) documented globally (Straatsma et al., 2017; Vörösmarty et al., 2010), as well as indicators related to the reduction of invasive species threatening ecosystems, habitats or species.

The application of NBS in cities, as well as their upscaling to peri-urban and natural settings to improve climate resilience will generate many unique opportunities for enhancing and improving nature characteristics, especially if designed and integrated into the process from the start. Multifunctionality across water-nature-people sectors is a key benefit to be gained through the implementation of NBS. Interdisciplinary approaches will be needed, however, to combine ecological comprehension within the systems thinking framework of NBS, locating them not as individual elements, afterthoughts or as part of a treatment train, but in connection with the wider social ecological framework within the landscape in question (Lähde et al., 2019).

Notably, the rapid urbanization observed worldwide has led to a fast and sometimes chaotic development of areas located especially at the fringe of existing cities, or rural and secondary towns (Lemaire et al., 2020). This evolution has contributed to the development of heterogeneous patchworks of residential, rural and natural areas constituting peri-urban catchments (Eakin et al., 2010). These new landscapes and the resulting mixture of activities that define them (e.g. agriculture; grazing; (small) industry; residential settlements; forest) are having profound effects on their surroundings, impacting both habitat structure and biodiversity, as well as water quantity and quality. Importantly, catchment flow regimes may be modified by the coexistence of mixed response times (related to water challenges), stemming from the mix of more impervious urban-drained to the more natural/rural-drained features, resulting in reductions in evapotranspiration and base flow as well as enhanced loads of xenobiotic pollutants discharging in counterintuitive patterns (Walsh et al., 2005; Zoboli et al., 2019). Entering into this picture are NBS for enhancing cities' resilience that should be scalable from cities to watersheds.

Although the two larger nature goals are further delineated separately herein, it should be recognized that the inherent consideration of, and any changes to habitat structure (area, heterogeneity, connectivity) will directly influence biodiversity, either positively or negatively, which may or may not be completely predictable within the immediate context of NBS upscaling. This means simply that we are entering new territory with respect to nature indicators, and that the context of including nature characteristics in the design of NBS means the timeline for documenting related changes, either positive or negative, may be unknown. This is somehow visible already, i.e. reflected in the data available for documenting changes related to nature regardless of the solution implemented. However, their inclusion is vital for transitioning to a new paradigm, like the planetary boundaries framework discussed in (Steffen et al., 2015), which should better integrate people with nature while simultaneously enhancing the resilience of ecosystems. Without this interdisciplinary approach, integrated within large-scale solutions such as NBS, societies will continue to develop fragmented policies that will ultimately lead to 'wicked' conflicts between the "environmental" sustainable development goals (SDG), and "socio-economic" SDGs (Randers et al., 2018; Sørup et al., 2020).

2.3.2.1 *Improving Habitat Structure through NBS*

Habitat structure refers to any quantitative changes in riparian, aquatic, wetland and terrestrial habitat types. These refer to habitats that are (i) associated with bodies of water (found along e.g. stream banks or other moving bodies of water), (ii) water-based, including areas only occasionally covered by water, (iii) land covered by shallow usually slow-moving or stagnating water, and (iv) land-based habitat such as forests, grasslands, deserts, etc., respectively. It additionally encompasses changes to e.g. urban green areas, which may form crucial components that further support changes enhancing key features such as habitat connectivity. These changes can thus be documented both in terms of quantity (specific areas, or changes in habitat boundaries), as well as quality. Habitat quality will additionally give insights into ecological state, in terms of the degree of fragmentation (or connectivity) and land use type (low impact space; diversity of land use; changes in land cover, etc.) that may arise and be of concern especially in e.g. peri-urban catchments. Finally, it can include the conservation status (related to trends in range, structure and function for species) of protected habitats (i.e. in conjunction with the EU Habitats Directive).

Structural heterogeneity has been suggested for use as a proxy for documenting biodiversity potential in a recent study of NBS implementation in cities (Monberg et al., 2018), denoted SUDS. In general, ecosystems are adapted to structural habitat heterogeneities, where habitat preferences may even change within a species life cycle (e.g. aquatic invertebrate taxa), indicating the importance of mosaic habitat patterns on a microscale (Hauer et al., 2018). In Monberg et al. (2018), this was recognized and implemented by adapting a set of standard SUDS to create "bio-SUDS". This meant redesigning a series of standard elements (infiltration trenches, curb extensions, rain gardens, swales, wet and dry basins) to increase the number of structural elements, where the most commonly chosen features included increasing terrain differences, meandering edges, sediment diversity (stones, cobbles, boulders), deadwood, and brown roof-like vegetation. They furthermore developed a "bio-SUDS" index for habitat heterogeneity, based on the registration of 45 structurally important components, which could assist future assessments of ecological quality in NBS design. Note that habitat quality may possibly play a larger role when upscaling NBS outside of cities for peri-urban and rural settings, where many more opportunities may become available. This is evident in the large documentation of small-scale NBS within cities, where the focus has typically been focused on increasing habitat quantity (see Monberg et al. (2018) for further details).

As an example for enhancing especially habitat quality within a peri-urban area (focusing on e.g. reducing fragmentation and enhancing species diversity when re-designing green spaces), Aarhus Municipality carried out a series of smaller-scale NBS within the city of Lystrup aiming at both, securing climate adaptation of the area as well as increasing biodiversity of a public green space (Knudsen and Stage, 2016). The largest of the constructed NBS in the area, Hovmarksparken, has been established as a public park. Creation of an artificial lake (rainwater retention basin) in the park was supported by combining many initiatives enhancing biodiversity in the area, including reintroduction of plant species, removal of nutrient rich soil and replacement by nutrient poor topsoil (to enhance terrestrial biodiversity). This project had a special focus on citizen participation during the design phase of the project, collecting data on flood-prone areas as well as gaining insights into how citizens wanted to use the re-designed space (Aarhus Municipality and Aarhus Vand, 2017). This has resulted in a multi-functional space consisting of a NBS with a focus on enhancing biodiversity and recreational value, as this area now brings people together in terms of the setting (artificial lake), grazing cows (for further enhanced biodiversity, as well as organic meat). Recently, a new study by (Knudsen et al., 2019) has been testing the potential for participatory events to enhance the connection between the re-established habitats and the local population. The aim of the events is to use these spaces to demonstrate the importance of biodiversity, which can be rehearsed and sensed by local communities. The results of these experimental participatory events show a success in producing and cultivating cultural and local knowledge and affective belonging to the restored area (Knudsen et al., 2019).

Structural restoration will not necessarily translate into positive ecological responses, however, and data on these are typically scarce (but see (Schirmer et al., 2014)). This was shown by (Haase et al., 2013), who investigated the effects of 24 hydro-morphological river restoration projects carried out in Germany. While hydro-morphology changed significantly in the restored sections, differences in restored and unrestored sections in terms of biological parameters were lower, similar to findings from other studies (Palmer et al., 2010). In fact, positive effects were observed only for fish (in 11 of 24 cases), and only one of the 24 restored sections returned to a "good" ecological state as required by the European Water Framework Directive (WFD). Recognizing the importance of stressors other than hydro-morphological degradation, (Haase et al., 2013) emphasized the need for catchment analyses that also consider water pollution (quality) parameters, source populations and dispersal capacities of sensitive species, and recommending the inclusion of societal and stakeholder perspectives when assessing initial successes of restoration projects.

2.3.2.2 *Supporting Biodiversity through NBS*

Biodiversity refers particularly to documenting changes related to e.g. type and density of native species (richness and composition), number and type of protected species, as well as factors related to invasive species that represent disturbances to ecosystems which should be maintained (at least not further degraded) or even enhanced where possible.

In one of the most successful cases ever documented, mitigation of fluvial flood risk (decreased flood stage of -24 cm) through restoration of embanked floodplains along the Rhine River delta (including all 3 distributaries in the Netherlands) has also proven successful in enhancing biodiversity (Straatsma et al., 2017). Over 76% (137 out of 179) of all examined fluvial floodplain sections showed an increase in characteristic and endangered species of birds, mammals, and fish, as well as dragon- and damselflies. Notably, after 15 years of river restoration, mostly the fast-spreading species have shown increased presence. Most species of herpeto-fauna and higher plants were not yet able to colonize created habitats, despite increased habitat suitability of the floodplain sections. Habitat restoration alone is therefore not necessarily enough for full biodiversity recovery, due to the presence of multiple stressors both within and outside of the floodplain areas.

Climate change adaptation and sustainable flood management are seen as emerging drivers of river restoration. In Switzerland, river revitalisation is required by legislation as a part of their flood protection measures (BWG, 2001). However, there are many complex underlying processes, i.e. physical/structural, biogeochemical (e.g. nutrient turnover) and ecological, that must be understood in order to achieve goals related to enhancing biodiversity and preventing potential adverse effects (Schirmer et al., 2014). The peri-alpine formerly braided Thur River in NE Switzerland (RECONECT Deliverable D2.3), is a good example, having been channelized in the 1890s to protect the river valley against flooding. Draining a catchment area of 1730 km^2, the Thur River is currently the largest river in Switzerland without a retention basin, leading to a very dynamic discharge regime ranging from 3 to 1100 m^3s^{-1} (Schirmer et al., 2014). Since 1993, several 1–3 km long river sections were widened by removal of stabilizing elements to allow the formation of alternating gravel bars colonized by pioneer vegetation and to increase hydrological connectivity between the main channel and its riparian zone. By comparing a restored and unrestored section of the Thur river, (Schirmer et al., 2014) have shown that, 12 years after the restoration took place, the species richness of plants and soil organisms (earthworms, arthropods, testate amoebae, bacteria) was higher in the restored section than in the control section (pasture) located directly upstream (Fournier et al., 2012a, 2012b; Samaritani et al., 2011). Importantly, this study also illustrates the complexity of and resulting need for holistic interdisciplinary efforts to assess key processes that influence biodiversity.

NBS involving river restoration, however, might not always increase an overall species richness. When setting biodiversity goals in NBS projects, it is important to also consider specific conservation goals for the area. Many characteristic species of dynamic floodplains have become endangered and therefore, the return of such species as a result of NBS should be considered as a success. For example, restoration of the Thur River, which promoted development of the gravel bars habitat resulted in the return of the little ringed plover after more than 100 years of absence (Schirmer et al., 2014).

Processes that are positive for nature, may ultimately lead to unintended (negative) consequences for e.g. people. For example, increased river dynamics, driven by short-term perturbations such as periodic floods and inundations as found by (Schirmer et al., 2014), led to increases in taxonomic and functional diversity as a result of periodic flooding. However, repeated flooding may become an issue if excessive erosion threatening valuable land occurs, that may test "the tolerance of the community and regulators on how far restoration can or will be accepted"

(Schirmer et al., 2014). Moreover, they mentioned that increased river dynamics may both negatively and positively impact the microbiological and chemical quality of drinking water collected by river bank filtration (commonly used in Switzerland), due to higher infiltration rates and shorter residence times within the aquifer as a consequence of such changes.

The RECONECT Demonstrator B site in Aarhus, Denmark can also be used to demonstrate planned and unplanned consequences related to their NBS. Lake Egaa, an artificial lake, was originally established in 2006 to reduce nitrogen impacts in coastal areas (thereby connecting water quality to ecosystem health). In the design of this NBS, several small islands were created to additionally provide habitat for birds, and the original course of the stream was kept (not filled in) to facilitate e.g. sea trout in migrating to their spawning grounds (Århus Amt, 2005a, 2005b). Today, more than 10 years since its establishment, a number of positive and negative effects can be documented. Positive effects include the lake's ability to act as a buffer for intensive (cloud burst) rain events, preventing the flooding of a residential settlement located downstream of the lake on the coast, which is enhanced by the use of the surrounding meadows for grazing (Nielsen and Hald, 2010). Moreover, within a couple of years, birds began to return to take advantage of the habitat afforded by the islands, now hosting several rare and unusual breeding birds (Grøn, 2010). However, sea trout populations have been heavily impacted, with reductions of up to 83% documented, meaning that trout stocks are no longer capable of reproduction, which is a problem for the local part-time fishers (Kristensen et al., 2014). They have attributed this to rising water temperature and decreasing flow throughout the season, making conditions for smolts less habitable. In addition, concerns are rising about the bird populations as sedimentation of the lake enables foxes to reach the islands endangering their usefulness (Knudsen and Stage, 2016).

Importantly, river restoration activities may be challenging for the native vegetation and the colonization process (Lapin et al., 2016). Restoration activities can, in fact, be regarded as disturbances that facilitate biological invasions, particularly in the case of alien plant species, which are the second most significant cause of extinction (Pagad et al., 2015). Over the past 40 years, damages to ecosystem services and human well-being from invasive alien species (IAS) have also increased dramatically (Ehrenfeld, 2010; Pejchar and Mooney, 2009). In the study by (Lapin et al., 2016), they focused on the influence of plant-IAS on newly created river channels of the Traisen River (Austria), where especially the seed bank of IAS is considered to be a limiting factor in achieving the goals of river restoration programs (O'Donnell et al., 2016). It was shown that the occurrence of IAS above ground and seeds decreased while the occurrence of target species increased, as a result of proper management of soil movement (Lapin et al., 2016).

In summary, to maximize the positive effect of NBS on biodiversity, there is a need for river restoration designs that incorporate requirements of fast, as well as slow spreading specialists and generalists. Removal of dispersal barriers to facilitate recolonization of habitats and optimization of abiotic conditions to support specialists also needs to be incorporated into designs from the beginning. Supporting the competitiveness of native plant species is an important tool for reducing the danger of the establishment of IAS, and recognition that restoration is a disturbance event must be taken into account already during the planning process. Finally, when considering NBS design, the temporal scale will be crucial when it comes to documenting changes related to nature, a concept recognized also by (Cohen-Shacham et al., 2019) as currently lacking within the NBS framework.

2.3.2.3 Conclusions and Remaining Gaps

Although the Water Framework Directive requires a good chemical and ecological status of all surface waters and the directive has been adopted for almost 20 years it is difficult to identify case studies that exemplify how NBS may positively (or negatively) impact nature (and preferably with people simultaneously). This highlights either an inherent difficulty or paucity of data required to clearly document such changes and/or interconnections (i.e. between benefits of the recorded NBS across the different areas (socio-economics, biodiversity, management, etc.). In some cases, these types of (interconnected) benefits were recognized, having been stated as part of the project objectives, yet the results related to those goals appear to have had a secondary role, if they are estimated at all. One reason for this may be that the interconnectivity of the various goals was not the main focus, as most of the cases were strictly classified according to one or another perspective (e.g. strictly Ecosystem Services, mainly Habitat Restoration, etc.).

Alternatively, changes documented in particular for habitat quality and biodiversity within many NBS may well have been a by-product (added value) not originally incorporated into the original design, indicative of the large potential for missed opportunities when nature is not properly considered from the outset. This can also lead to negative or unintended impacts, for example, if people want better access to e.g. rivers and streams, which is possible when re-meandering or other retention-enhancing solutions are chosen in conjunction with NBS. However, this can result in the complete removal of vegetation along the water course, which will reduce shading thereby exacerbating climate change impacts related to increasing stream temperatures, especially in summertime.

Notably, it was found that much greater attention has in fact been given especially to the socio-economic benefits of NBS (described in more detail in the next section), thereby underrating their effects on nature and disregarding the common goals that clearly exist between these two areas. Whether this was a conscious choice in the creation of these databases, i.e. in order to help simplify the search for specific applicable solutions, the result is that many of the NBS applications and possible benefits are excluded, or underestimated.

2.3.3 *NBS for the Benefit of People*

NBS can provide a range of social and economic benefits, with important implications for human health, wellbeing and livelihoods. Integrating NBS into flood management and planning processes offers a range of such co-benefits, while increasing resilience and sustainability. As NBS may include a wide range of solutions, such as tree-planting, parks and open spaces, stormwater management such as retention ponds, restoration of urban rivers or streams, creation of green roofs, urban agriculture, and living shorelines, co-benefits will be specific to the particular social, ecological and technological contexts (Keeler et al., 2019).

Socio-economic benefits of NBS include green jobs, tourism and business opportunities and increased property values. There are also socio-cultural co-benefits linked to improved cultural and recreational opportunities for residents, as well as promotion of social cohesion and social justice if equality considerations and power relations are included in planning NBS (Andersen et al., 2017; Sørup et al., 2019). In terms of benefits for health and wellbeing, these include improved psychological and physical wellbeing, due for example to better air and water quality and increased access to green spaces. These contributions to human wellbeing and socio-economic benefits are important to consider in planning NBS, as they contribute to potentially cost-efficient, comprehensive, and multifunctional solutions to manage hydro-meteorological risk. This section describes the state-of-the art with respect to these dimensions, termed here contributions to ‘People’.

2.3.3.1 *Improving Socio-Economic and Socio-Cultural Benefits through NBS*

NBS is an emerging concept, but builds on several decades of work focused on how management of the natural environment can offer co-benefits for the economy, society and ecosystems in urban and rural landscapes. A key consideration for NBS is how they offer more efficient and cost-effective solutions than traditional solutions. In particular, in a risk reduction context NBS offer a potentially cost-efficient form of climate change adaptation (Brink et al., 2016). In this way, NBS have potential to be a major contributor to the development of a 'green economy' (Nesshöver et al., 2017). This results from a range of socio-economic and socio-cultural co-benefits that can be obtained from NBS (e.g. tourism, business and investment opportunities, and enhanced property values).

To understand these co-benefits, more work is needed to compare the multiple values of NBS (e.g. green infrastructure), to that of more conventional forms of infrastructure, such as grey infrastructure and technological solutions (e.g. sea walls, levees and irrigation systems). The value of such options, such as rain gardens or green spaces, could be reported narrowly in terms of the cost savings of avoided water treatment, or from a broader perspective to more comprehensively take into account a range of potential health and social co-benefits (for example, improved aesthetic quality, reductions in carbon emissions due to change in travel behaviour, improvements in safety, and improved social cohesion). Given the limited attention to broader co-benefits, NBS may be undervalued as their synergistic economic, cultural and health benefits have not been fully investigated (Hunter et al., 2019). Better valuation also requires shifting political and economic paradigms towards those recognizing more long-term benefits that can be provided by NBS. Comparing NBS to other types of solutions also requires comparative data to allow decision-makers to compare costs and other important criteria. More comprehensive economic valuation of benefits is critical to support decision-makers and planners, and can lead to identification of cost-sharing opportunities, which can build wider support for NBS and contribute to long-term sustainability.

Potential negative socio-economic impacts should also be taken into account, which also affects the relative value of NBS compared to other options (Keeler et al., 2019). For instance, vegetation may require irrigation and large demand for water resources, which may not be cost-effective in drier climates. Tree roots can cause damage to other infrastructure, with repair and legal costs (Mullaney et al., 2015). Vegetation can also contribute to nutrient pollution, and result in harmful pests and risks of pollen allergens, with associated health costs without adequate maintenance (Churkina et al., 2017; Janke et al., 2017).

Implementation of NBS can make important economic contributions particularly towards environmental protection and disaster risk reduction measures, and creation of green jobs. NBS can provide cost-effective options to manage climate impacts, contributing to adaptation and mitigation (Brink et al., 2016). As ecosystems are renewable they may be associated with lower maintenance costs and longer lifetimes compared to technical systems for environmental protection. For instance, natural water retention measures have been demonstrated as cost-effective solutions to reduce flood risks (Strosser et al., 2015). The contribution of NBS to increased resilience means that such solutions also have insurance value.

Highlighting the above mentioned values of NBS is the main aim of Eco:Actuary, an insurance industry-relevant policy support system to be applied on the HORIZON 2020 NAIAD project partners. In particular, Eco: Actuary is able to assess the impact of NBS on local and downstream assets at risk of flood, as well as calculating the economic value of such assets (King's College London and AmbioTEK, 2019). The application of Eco:Actuary on NAIAD cases such as the Lower Danube Demonstration site (Romania) was the baseline to identify proper business cases for NBS implementation and increase stakeholder risk awareness (NAIAD, 2019a). As another NAIAD example, the Glinščica Demonstration Site (Ljubljana, Slovenia) defines as one of its main goals to state the importance of understanding the value of ecosystems in the long run. In order to do that, they aim to develop and deploy nature assurance schemes for effective business models in the field of ecosystem services, green infrastructure and river restoration (NAIAD, 2019b).

Natural assurance schemes (NAS) are NBS that capture the insurance value of ecosystems. Insurance value is based on an ecosystem's capacity to remain in a given regime and retain its capacity to provide critical ecosystem services during a disturbance (Denjean et al., 2017).

NBS in the form of green infrastructure can increase the attractiveness of green and blue areas compared with grey infrastructure (Raymond et al., 2017a). This provides a number of economic benefits linked to green jobs and tourism. For instance, NBS plays a critical role in the hotel industry (Han and Hyun, 2019). Although there are a range of socioeconomic benefits associated with NBS and associated ecosystem services (Maes and Jacobs, 2017), realizing these requires overcoming existing political and economic barriers, such as shifting subsidies for fossil-fuel consumption and overcoming short-term interests of private actors and governments.

NBS provide an opportunity to address concerns of social justice to ensure that investments do not exacerbate inequalities (Haase, 2017). For instance, green spaces can promote a sense of belonging and place and reinforce cultural identities (Hartig et al., 2014; Keniger et al., 2013). However, green developments may also only provide disproportionate benefits to residents with higher socio-economic status, and contribute to displacement and gentrification. Although NBS cannot resolve underlying inequalities, considering such power structures is important to ensure they offer positive benefits for poorer residents (Curran and Hamilton, 2012; McKendry and Janos, 2015). Participatory governance models are being developed to better implement NBS to tackle such inequalities and power relations (Kabisch et al., 2016).

The winner of the Living Waterways Award for “Engaging Communities – Large-scale”, the project Canal and North Gateway in Glasgow, run by the Scottish Natural Heritage, has community engagement and urban regeneration at its core. Scottish Canals and the Glasgow city center run extensive community engagement sessions before the start of the project. 30,000 visitors have been recorded in the first six months since the opening, and the construction of this NBS has coincided with the opening of a new a new health centre (specialising in addiction and child/adolescent mental health services) nearby. Thus opening the possibility of a space for “green prescriptions”. Moreover, the project has occupied and regenerated abandoned and derelict areas of the city, and contributed to habitat enhancement work (e.g. woodland regeneration, restoration and monitoring flora and fauna) (Scottish Natural Heritage, 2019).

Another case study of a large-scale NBS is the Laojie River project in Taoyuan in Taiwan. The study focused on changing the channelized, culverted, flood-control water course in to an accessible green infrastructure corridor for the public (Chou, 2016). The landscape changes resulting from this project have increased recreational activities and improved the aesthetic value in the area.

Community gardens and other green spaces can improve community cohesion and strengthen social networks across different groups if designed with inclusivity in mind (Cameron et al., 2012). Nature experiences may also have greater benefits for disadvantaged groups, and thus could contribute to reducing inequalities in wellbeing and other outcomes (Mitchell and Popham, 2008). As poorer neighbourhoods are often more deprived, safe and accessible green spaces may make significant contributions to social cohesion and wellbeing (Andersson et al., 2015). Social justice contributions require further research to value this benefit of NBS. For instance, normative and ethical aspects, such as who are the winners and losers, especially in relation to processes that put people at risk from climate-related hazards (Brink et al., 2016). This requires considering different types of exclusion, and their spatio-temporal variations in order to ensure inclusive design.

Cultural benefits from nature are wide-ranging and critical for human wellbeing, although they may be harder to quantify or value. The M (Millennium Ecosystem Assessment, 2005) describes cultural ecosystem services as benefits including cultural diversity, spiritual, and religious values, knowledge systems, educational values, inspiration, aesthetic values, social relations, sense of place, cultural heritage values, recreation, and ecotourism. For instance, aspects of cultural heritage including traditional land uses or the importance of certain endangered species indicate the importance of natural environments to sense of place (Satz et al., 2013). These cultural benefits can also be divided into services (e.g. aesthetic value of the landscape), goods (e.g. educational opportunities), benefits (e.g. sense of place), and activities (e.g. hiking, fishing, gardening). Nature environments can offer a range of different cultural benefits, for instance a review of cultural benefits of marine sites found benefits including engagement and interaction with nature, place identity, therapeutic value, social bonding, spiritual value, and memory/transformative value (Bryce et al., 2016).

The Support Association for Regional Traditional Orchard Cultivation (Födergemeinschaft regionaler Streuobstbau, FÖG) has created a case with the objective of restoring traditional orchard meadows in the Hessen/Baden-Wurttemberg area in Germany. The main drive for this NBS was the preservation of the traditional landscape element and its environmental value with a focus on biodiversity. Moreover, the additional educational function of this traditional environment is increasingly gaining attention, feeding into the contribution to rural vitality (Hülemeyer, 2016).

Another example is the case of the city of Rome within the EnRoute project. One of this case's goals is to create a connection between the Cultural and Natural Capitals in the dense urban settlement of the II District. The developed NBS had to connect the need of more public green spaces with the creation of landscapes suitable for the support of wild bee populations, effectively creating a synergy between biodiversity conservation/restoration and the enhancement of ecosystem services provision capacity (Capotorti et al., 2019; Fusaro et al., 2017).

Some cultural benefits are more intangible, such as identity, sense of place, and the symbolic importance of green infrastructure, which makes them harder to account for in planning and decision-making despite their importance (Russell et al., 2013). For instance, a proposed 'sell off' of public forests in England managed by the Forestry Commission resulted in large protests due to both individual and shared meanings linked to such environments (Irvine et al., 2016).

Cultural values have often been under-represented in environmental management decision-making, partly due to challenges in defining and measuring these benefits. For instance, compared to approaches for quantifying physical access to green space, measuring cultural access has been overlooked, which refers to what level people perceive they have the right to use an area.

2.3.3.2 Improving Health and Wellbeing through NBS

The World Health Organization defines health as 'Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.' NBS can make important contributions to promoting these dimensions of human health and well-being in many ways (Carrus et al., 2015; van den Bosch and Ode Sang, 2017). These benefits from access or exposure to natural environments occur through a range of direct and indirect pathways (Kabisch et al., 2017). Health benefits are closely linked to socio-economic benefits, for instance, investing in trails for walking and cycling that lead to increased recreational activity can result in saved healthcare costs.

These benefits can be obtained from health promoting opportunities, such as by encouraging healthy behaviours. Societal interventions such as investments in spaces for physical activity and recreation can play an important role in combating non-communicable disease (NCD). NCDs including diabetes, obesity, chronic respiratory diseases, cancer, mental and cardiovascular disorders, constitute a major global disease burden (Vos et al., 2017). Health promoting environmental interventions can provide population-wide improvements in health and long-term effects. For instance, green and blue spaces may offer recreational areas for swimming, boating and fishing (Reynaud and Lanzanova, 2017). NBS can provide attractive locations for cultural and recreational activities (Cohen-Shacham et al., 2016; Raymond et al., 2017a). Multifunctional blue and green spaces play an important role in quality of life, for instance water-based nature-based solutions are seen as peaceful, beautiful and values spaces that promote human wellbeing (Abraham et al., 2010; Spash, 2000). Increased use of these spaces can therefore contribute to reducing above-mentioned NCDs. Benefits to health may also come through natural environmental reducing risk. These benefits are obtained by protecting individuals from environmental exposures such as air, noise and water pollution, temperature extremes and associated diseases, such as respiratory disease, heat stroke, drowning, or infections from contaminated water. These benefits are context specific, as natural environments may have different meanings and functions, and thus health impacts in different cultural and ecological contexts.

The health benefits of green and blue spaces have been reviewed previously (e.g. (Gascon et al., 2015; Hartig et al., 2014; Triguero-Mas et al., 2015), however more attention is needed to health benefits in the context of NBS. For instance, health and wellbeing benefits could be more widely promoted as an outcome of NBS implementation, allowing greater cross-sectoral collaboration (van den Bosch and Ode Sang, 2017). In RECONECT health and well-being, contributions of NBS are divided into a series of sub-goals on physical health and wellbeing, psychological health and wellbeing, and air quality. Ways that NBS contribute to these sub-goals are described below.

There are a range of benefits to physical health and wellbeing linked to exposure to nature. A review conducted by (Twohig-Bennett and Jones, 2018) found that exposure to greenspace was associated with wide-ranging health benefits, including decreases in cardiovascular mortality, decreased risk of type II diabetes, and all-cause mortality. There are particular benefits for vulnerable age groups, such as the elderly and children. Children's cognitive, emotional, and motor development has been associated with exposure to nature (Dadvand et al., 2015). For instance, access to greenspace among children has associations with birth outcomes, obesity and overweight, asthma and allergy (Kabisch et al., 2017; Sbihi et al., 2015). Benefits to physical health may not be experienced equally across society, with socio-economic factors mediating benefits in some cases, potentially even contributing to exacerbating social inequalities.

A research conducted by (Tamosiunas et al., 2014) tried to assess the potential relationships between distance and use of urban green spaces and the prevalence of cardiovascular diseases and its risk factors in Kaunas City, Lithuania. The study showed how the prevalence of lifestyle-related and biological risk factors (e.g. smoking or obesity), and the prevalence of diabetes mellitus and cardiovascular risk factors was significantly lower among park users than among non-users. Following the results of the research, the authors request policies addressing public health and promoting healthy lifestyles in cities (Raymond et al., 2017a).

Blue spaces have also been linked to positive physical health outcomes, particularly due to opportunities for promotion of physical activity (Gascon et al., 2017). Blue spaces have been defined in the BlueHealth project (https://bluehealth2020.eu/) as “outdoor environments – either natural or manmade – that prominently feature water and are accessible to humans either proximally (being in, on, or near water) or distally/virtually (being able to see, hear or otherwise sense water). Less focus has been placed on the potential negative health outcomes related to blue spaces, and required planning and management needs (e.g. drowning, pollution, flooding, health risk due to mosquitos, etc.). In the case of NBS that are not concentrated on provision of green or blue spaces, there remain gaps in assessing other health benefits, such as occurring from improved water management or food supply. This may also be related to the limited number of studies from low- and middle-income countries.

Exposure to air pollution in cities is a major public health challenge. Air pollution due to traffic and industrial sources has a major impact on human health, and is linked to approximately 381,000 premature deaths annually in Europe (Lelieveld et al., 2015). These exposures are particularly detrimental for children and adolescents, as poor air conditions can have life-long impacts. For instance, children "suffer more from the negative effects of air pollution as shown by, for instance, the increasing prevalence of childhood asthma in urban areas (Clark et al., 2010). In addition, greater exposure often occurs in more marginalized neighbourhoods, which are closer to traffic or industry and with sparse vegetation or green spaces (Wolch et al., 2014).

If well planned and managed, green and blue spaces can contribute to reducing air pollution, as vegetation can improve air quality by removing air pollutants (Morani et al., 2011). Although positive impacts of air purification from vegetated spaces have been reported on a city scale, pollutant concentrations can be increased on a more local scale in hotspots due to the creation of street canyons. This complexity has implications for the effectiveness of NBS to benefit air pollution and requires attention to vegetation configuration, and meteorology (Vos et al., 2013). In addition, the effectiveness of vegetation to remove air pollutants depends on other factors such as type of vegetation, tree health, soil moisture availability and pollution concentrations (Baró et al., 2014).

Aiming to tackle poor air issues, despite being one of the largest cities in Europe and having a population density of around 16,000 inhabitants per square kilometer, Barcelona developed a green space extension that represents 36.8% of the city area. In 2008, the number of street trees across the city has doubled in the last 30 years. From 2009, the city committed to address urban environmental issues, with a series of projects including increasing the number of street trees and the provision of green spaces close to citizens (e.g. "Green 5 minutes from home"). This initiatives were driven by the desire of obtaining a series of ecosystem services, including improving air quality (Raymond et al., 2017a).

Benefits of air quality improvements must also be considered in the context of other benefits. For instance, highly maintained parks may remove fewer air pollutants than more natural areas, but may also be viewed as less appealing or unsafe to users, reducing cultural benefits. Species that may remove the most pollutants may be considered invasive to particular regions, and thus local ecological context should be considered to avoid conflicting with other potential benefits of NBS (Escobedo et al., 2011).

NBS offer a range of benefits for psychological health and wellbeing, such as lower risk of depression symptoms, psychological distress, etc. These benefits are due to both physically measurable aspects (e.g. aesthetics, safety, access) and individuals' perceptions. Mechanisms proposed for these benefits include: intrinsic qualities of green and blue spaces that improve health or well-being; the healthy environment associated with green spaces (lower temperature, air pollutants and noise have been observed in greener areas; the opportunity to perform physical activity; and the opportunity to enhance social interactions (Gascon et al., 2015). In the case of blue spaces, a positive association between exposure to outdoor blue spaces and mental health and well-being exists, but there is limited evidence on direct causation (Gascon et al., 2017).

In the case of green spaces, there are a number of benefits reported for mental health. High perceived naturalness (e.g. perceived proximity to a natural vegetation) has been associated with more activities, higher aesthetic values and self-reported well-being (Ode Sang et al., 2016). There are particular benefits for children's mental health such as behavioural issues and ADHD, due to the long-term impacts of exposure to environmental pollutants. In addition, green space has been found to reduce aggressiveness in adolescents (Younan et al., 2016). In rural areas, stress levels were found to be lower among children with high levels of nearby nature compared to those with little nearby nature (Wells and Evans, 2003).

A review of mental benefits of exposure to green and blue spaces suggests more in depth information is needed on the specific characteristics of the green and blue spaces that promote improved mental health, such as the quality and distance of these spaces, and the pathways through which benefits are obtained (Gascon et al., 2015). In addition, these benefits should be assessed according to differences in social class, education, age and gender, which may modify the extent of benefits from these spaces.

2.3.3.3 Conclusion and Remaining Gaps

The contributions to 'People' outlined here indicates the multi-functional and cost-effective characteristics of NBS. A remaining challenge is comprehensively assessing multiple co-benefits to People, as well as negative outcomes, as most work focuses on single benefits such as air quality (Haase et al., 2014). Overlooking multiple co-benefits risks undervaluing benefits or not accounting for potential negative consequences, such as how green spaces can provide benefits as water collection basins as well as providing recreational and cultural activities. There also remain a number of gaps in understanding for assessing the benefits of NBS in different settings, as there has predominantly been a focus on NBS in urban areas and cities, and in the case of urban ecosystem services research has largely been conducted in Europe, North America and China at a city scale (Haase et al., 2014). This results in limited knowledge of the benefits of NBS to people specifically in other geographic regions, such as rural or natural areas, and low- and middle-income countries. Compared to NBS, there is a larger body of work examining human health and wellbeing in relation to green and blue spaces, so this literature can provide relevant examples in areas where NBS have not yet been implemented.

2.3.4 Monitoring and Evaluation frameworks for NBS

There are several frameworks and methods that can be used to assess the performance indicators of NBS as shown by (Ruangpan et al., 2020). One of the most popular assessment approaches is to analyse, simulate and model hydrology, hydraulics and water balance processes (Lerer et al., 2015). This information is then used to support decision makers, planners and stakeholders in their evaluation of performance and potential of NBS by comparing modelled results against the current situation, baseline scenario or targets (Löwe et al., 2018). In addition to hydrological and hydraulic analyses, cost– benefit analyses are often used to select and evaluate NBS (Huang et al., 2018; Nordman et al., 2018; Watson et al., 2016; Webber et al., 2018) The common benefits considered include prevented damage costs, omitted infrastructures and prevented agricultural losses. One cost–benefit approach is to evaluate NBS by applying the whole life cycle costing (LCC) approach, including construction, operation, maintenance and opportunity costs (Nordman et al., 2018), and return on investment (ROI (De Risi et al., 2018)).

Another method for the evaluation of NBS is multi-criteria analysis (MCA), which has the potential to integrate and overcome the differences between social and technical approaches (Loc et al., 2017). It can be used to structure complex issues and help find a better understanding of costs and benefits. Such analysis is useful for decision makers when there are multiple and conflicting criteria to be considered (Alves et al., 2018; Brudler et al., 2016; Dong et al., 2018; Hennequin et al., 2018; Loos and Rogers, 2016; Sørup et al., 2019). The MCA takes different criteria into account and assigns weights to each criterion. This process can produce a ranking of the different measures that can be implemented on the site (Chow et al., 2014; Jia et al., 2015). For example, Loc et al. (2017) integrated the results from numerical modelling and social surveys into a MCA and ranked the alternatives based on the evaluation criteria of flood mitigation, pollutant removal and aesthetics. Loos and Rogers (2016) applied multi-attribute utility theory (MAUT) to assess utility values for each alternative by assuming that preference and utility are independent of each other. (Petit-Boix et al., 2017) recommended that future research combine the economic value of the predicted material and ecological damage, risk assessment models and environmental impacts of NBS even though this is by no means an easy task as demonstrated by (Dong et al., 2019, 2018). Since not all assessments can be done with modelling alone, interviews and fieldwork are often necessary.

The Horizon 2020 project OPERANDUM project (www.operandum-project.eu) has developed an indicator set based on best management practice (Rutzinger et al., 2019). The main message from both is that there does not exist a best practice indicator set for NBS and that specific projects has used indicators that was relevant in those specific settings. Likewise, indicator sets that try to incorporate all aspects along the three (Water, Nature and People) axes are not common and, hence, the level of interaction and cohesion between axes is a vastly underexplored area.

Following the EKLIPSE framework for evaluation of NBS impacts (Raymond et al., 2017a) the Horizon 2020 project Nature4Cities (www.nature4cities.eu) have evaluated a range of NBS projects that answers to specific challenges (Nature4Cities, 2019). The evaluations are very specific and do as such not provide a broader view to NBS implementation in general. The Interreg North Sea Region project Building with Nature (https://northsearegion.eu/building-with-nature/) has made a comparative evaluation of NBS river projects in Belgium, the Netherlands and Scotland in an attempt to facilitate a more general view to which factors characterize a good NBS river project (Huthoff et al., 2018). Earlier on the FP7 project DESSIN (https://dessin-project.eu) developed evaluation frameworks for water related Eco System Services (Ecological Institute, 2014).

2.3.4.1 *Monitoring and Evaluation Framework for RECONECT*

RECONECT has a broad approach to monitoring and evaluations in relation to the Demonstrators. Best practice regarding indicators that describes NBS performance is analysed in RECONECT Work packages 2 and 3 as a basis for selecting the indicator set used in RECONECT, see Figure 9, following the framing of the state-of-the-art sections of this report. Results are summarized in RECONECT Deliverable D2.3 and specific methodologies for the assessment of water, nature and people indicators are being developed and will be reported in appendices of RECONECT Deliverable D3.5.

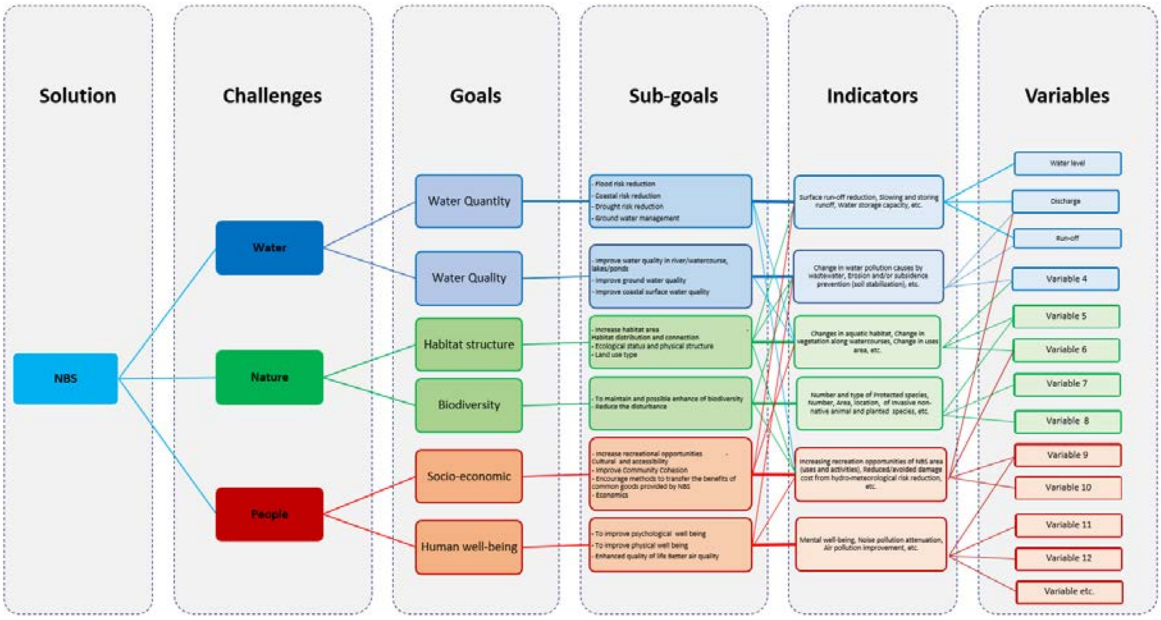


Figure 9 RECONECT framework for development of indicators and related variables

Monitoring and evaluation is covered in RECONECT Work packages 2 and 3 in relation to development of the specific monitoring and evaluation plans for the RECONECT Demonstrators. RECONECT Deliverable D2.6 focuses on describing the demonstrators' plan to evaluate the performance of their NBS in meeting the intended objectives or sub-goals (in relation to WATER, NATURE, and PEOPLE). Identified impacts (intended and unintended) of the NBS projects are presented, together with the selected indicators to monitor each of the impacts. Also, the monitoring plan to collect the data needed to assess the indicators is described. Generally, the methodologies for monitoring is very different whether water, nature or people indicators are the target.

2.4 Suggestions for Use

Having reviewed the existing literature on NBS and its sister concepts it is clear that large scale NBS is underrepresented in the literature and that there are no clear and agreed framework for assessing their performance, neither when compared to traditional methods, nor when more holistic frameworks are considered. Thus, this review has focused on services provided by NBS structured over water, nature and people related services. Large-scale NBS should combine these services best possible in relation to place-specific parameters and conditions. When considering the similarities across the three dimensions the main findings seem to be:

- There are many types of the hydro-meteorological events that can be addressed by NBS, including floods, droughts, storm surges, and landslides.
- There may be variations in which variables and indicators may be most important, but NBS seem to be applicable across the majority of locations, including estuaries, coastal, mountainous, or low-lying regions.
- The scale of implementation (e.g. national, regional, local) may have an impact on the analysis, but it is not possible to outline which framing is most favorable to NBS, nor which one would be most fair to apply.

Thus, future projects should combine knowledge from all these aspects and combine them into solutions that purposefully provide a range of relevant services. It might be that no single project exist already that can serve as a basis for conclusively identify the optimal solution for a given set of place-specific parameters, or even serve as inspiration. However, multiple projects that each solve specific parts of the problem definitely exist as illustrated by the many reference in this chapter to existing applications and assessments. Further, the importance of monitoring and evaluation then become clear as new combinations of NBS and provided services might entail side effects (positive or negative) that needs to be addressed and documented for others to learn from.

People seeking to design a large-scale NBS can in this chapter find good examples of how NBS has been implemented to solve specific, often case-specific, problems in relation to water and nature management as well as the services that NBS can provide for people. The chapter can serve as a good starting point for finding relevant indicators and examples of using them in relation to assessing NBS in a given context.

3 NBS Relevant Policy Frameworks

3.1 Setting the Scope

With the introduction of the concept of NBS by the International Union for Conservation of Nature (Cohen-Shacham et al., 2019, 2016) and the European Union (European Commission, 2020), also research focusing on public policy and governance has gained more prominence in recent years (Nesshöver et al., 2017). In this context, a large number of long-term research projects have recently been funded that are trying to explore which policy and governance frameworks are particularly effective in ensuring the amplification of NBS across scales and sectoral contexts (see Table 1).

Table 1 Selection of EC funded NBS projects with a focus on policy and governance

Acronym / website	Policy and governance related aspects	Sources
ThinkNature www.think-nature.eu	- Case-study based analysis of barriers and decision-making processes for realizing NBS with a focus on urban areas - Handbook with a dedicated section on policy and decision-making	(Bernardi et al., 2019; Thinknature, 2019)
NATURVATION naturvation.eu	- Systematic literature review of governance mechanisms as well as successes and barriers for uptake of NBS - Review of European and national policy frameworks	(Davis et al., 2018; Sekulova and Anguelovsk, 2017)
PHUSICOS phusicos.eu	- Case study based analysis of governance innovation	(IIASA, 2019; Martin et al., 2019)
Connecting Nature connectingnature.eu/	- Governance Guidebook	(Vandergert, 2020)

In addition, efforts are undertaken to document case studies of NBS application in online databases to showcase good practices of NBS realisations, including information on policy and governance (e.g. organizational structures, project coordination, participation level, institutional setting, financing model, and property rights) (see Appendix A).

However, although a systematic assessment of the successes and challenges in the governance of NBS across different contextual settings and by relying on different policy frameworks is critical for understanding the key drivers for the uptake of the findings of research and innovation projects, there exists only very few studies with an explicit focus on policy and governance. There is thus a need, to more thoroughly analyse “supportive policy frameworks, as well as factors of political and social resistance to change at relevant levels, and addressing the consistency of different policies and approaches for integrated spatial planning and efficient NBS deployment and overcoming some trade-offs” (Bernardi et al., 2019, 82). The role of policy frameworks for uptake of NBS is discussed in section 3.2.

In this chapter, we provide a synoptic overview on some of the key drivers and institutional barriers that support or hinders a more effective uptake of NBS. The chapter is based on a literature review as well as a review of insights produced in previously EC funded NBS projects with a focus on policy and governance as well as on an analysis of existing NBS databases (see Table 7 in Appendix A). Based on a systematic search of existing project databases (e.g. BISE, Climate-ADAPT, OPPLA, etc.), 408 case studies that implement NBS were identified. These were then classified according to: (1) their benefits, (2) the societal challenges addressed, (3) the climate risks addressed, (4) the policy framework, (5) the overall project cost and (6) the sources of funding used for implementation of the NBS. The outcomes of the analysis are presented in section 3.3.

3.2 How Do Policy Frameworks Include the Uptake of NBS? Insights from a Literature Review

Policy frameworks include different instruments, such as directives on the European level, general strategies, programmes and specific financing mechanisms. This section is particularly focused on whether and how different policy instruments address NBS and related concepts, and to what extent they promote their uptake. The key insights are provided below. They will also help to identify some of the challenges to be expected for RECONECT Demonstrators and Collaborators.

3.2.1 Policy Plays a Key Role in the Uptake of NBS

Generally, there are various policy-related drivers and barriers shaping the uptake and amplification of NBS. As Bernardi et al. state: “policy issues are fundamental in the formation of the driver-barrier landscape of NBS” (Bernardi et al., 2019, pp. 149–150). However, there is no single policy solution that best support NBS. Due to the relative novelty of the term and due to the variety of societal challenges that can be addressed by NBS, there is neither a singular legally binding framework nor a unifying policy framework on the European level that addresses the uptake of NBS systematically and co-ordinately. As Davis et al. put it: “[T]here is currently only uncoordinated legislative and financial support for NBS scattered in various policy document and sectors” (Davis et al., 2018). This is further supported by our findings from an analysis of existing NBS databases (see section 3.3).

3.2.2 The Realisation of NBS Requires a Policy Centric Governance Approach

In-depth case study research (IIASA, 2019) indicates that NSB require the involvement of different actors both within and outside of public administration as well as the effective interplay of different policy framework located at multiple institutional scales and within multiple sectors. In three case studies analysed in-depth by the PHUSICOS-project, actors and policies from flood and landslide protection, from nature conservation, urban planning, water quality, waste management, tourism, recreation, and many more administrative responsibilities were included. This findings highlights the fact that while NBS are realized on the local level, the wider institutional and inter-institutional context needs to be considered to strengthen more comprehensive and mutually supportive policies (Wamsler et al., 2017).

Particularly on the European level, a variety of relevant policies exist. In total, Davis et al. identified 23 EU instruments that directly or indirectly address NBS related topics (Davis et al., 2018). The instruments are distributed across different policy fields, including biodiversity, water, marine environment, forestry, agriculture and regional policy, climate change adaptation, research, cohesion and growth and as well as environmental assessment. This finding highlights, that it is rather a bundle of policies established in different sectors and across different scales that need to be in place to ensure an effective amplification of NBS: “[…] all relevant policies should be streamlined to support NBS. The key to change is to support new ways of comprehensive thinking with regard to the policy instruments” (Thinknature, 2019, p. 150).

The need for a more comprehensive perspective also becomes apparent when looking closer at the challenges addressed by NBS: The policy instruments reviewed by Davis et al., (2018) address a variety of societal challenges. They found that “green space, habitats and biodiversity” is the single most often identified challenge.

3.2.3 Long-Term and Coercive Policies are Needed for the Amplification of NBS

Mainstreaming NBS needs a long time horizon and policies need to be effective. Therefore long-term policies should not just create a stable and supportive environment (e.g. for investment), such policies should also be coercive and actively enforce the realization of NBS (Thinknature, 2019). A mixture of incentives and strong regulations are needed to promote and enforce the uptake of NBS, this includes regulations on the EU, national and regional levels as well as concrete local strategies and plans (e.g. climate change adaptation strategy, land use planning). This includes a wide range of policy instruments (e.g. laws, norms, strategies, planning instruments, funding programs, incentives, and investments) supporting the realization of NBS.

However, current policy instrument are rather conservative and less enforcing in their orientation. While most instruments reviewed by Davis et al. (2018) highlight the relevance of NBS and related nature-oriented/based approaches, “they often do not state how or in what way action should be taken” (Davis et al., 2018, p. 19). Predominantly, policies encourage or support the maintenance of existing green and blue spaces; to a lesser extent, they emphasize the restoration of ecosystems and their functions. Generally, Davis et al. conclude that the results of their analysis “underscore the current focus of EU policies to manage/maintain and restore existing ecosystems, rather than emphasizing the creation of new spaces” (Davis et al., 2018, p. 19). Therefore, most instruments are based on statements that require no specific actions or, if at all, voluntary actions. Most common are statements that highlight the benefits of NBS or encourage at least their uptake. More binding statement are rare and occur most often in relation to the creation and maintenance of NATURA 2000 sites. However, still a considerable number (i.e. 31 % of the reviewed policies) are characterized by a “strong explicit support” of NBS (“NBS or related terms are explicitly mentioned and strongly embedded throughout the framework, including in objectives, policy measure design and/or supported actions” (Davis et al., 2018, p. 44). This among others includes the EU Biodiversity Strategy, Green Infrastructure Strategy, Marine Strategy Framework Directive, Forestry Strategy and the Adaptation Strategy.

In addition, The ThinkNature project has identified the following policy instruments as particularly effective: land use planning, authorisation procedures, information steering, fees, payment facilities (e.g. exemption from storm water charges), tax deductions, jurisprudence, penalties, agreements, persuasive guidance (e.g. expert assistance and knowledge-based facilitating), as well as obligations to implement NBS along with new construction projects and investment support.

3.2.4 Economic Instruments for NBS are a Decisive Tool for the Realisation of NBS

Mainstreaming and upscaling NBS require large and sustainable flows of finance. It requires support for new finance and business models across private investors, governments, companies and industries. So far, the current financing of NBS has been wholly or at least partially supported by public investment (Frantzeskaki et al., 2019). One of the challenges to secure private investment is that return on investment of NBS involves higher risks and long-term revenue horizons. Novel valuation and accounting methodologies for NBS are needed to be adjusted for long-term public value. In detail, applying real options valuation instead of simple Net Present Value (NPV) valuation procedures are suggested to aggregate all values over time (Toxopeus and Polzin, 2017). Another challenge is, when the payoffs include public benefit, such as flood protection, it is difficult for investors to reap them (Toxopeus and Polzin, 2017). Some argue that different financing strategies are needed for different types of NBS (Toxopeus and Polzin, 2017). Considering urban gardening has more value proposition for private investors than creating green spaces in terms of its payoffs, deploying different and novel financing models that satisfy both private investors and public benefit should be identified (Frantzeskaki et al., 2019). Some research suggested several innovative private and public funding solutions such as alternative financing schemes based on crowdfunding to foster public-private partnership, Social Impact Bond (SIB) schemes, or Tax Increment Financing (TIF) (Huston et al., 2015). The ThinkNature project also identified economic strategies supporting the realization of NBS, including environmental taxes, price-based instruments, carbon trading schemes, biodiversity offsets, certification, payments for ecosystem services, fiscal benefits, etc. There might also be a combination of these (Thinknature, 2019).

3.2.5 Collaboration and Co-creation is Relevant and Should be Enforced Through Policies

Stakeholder involvement is considered essential for the realisation of NBS (Albert et al., 2019; Murti and Mathez-Stiefel, 2019; Santoro et al., 2019; Sarabi et al., 2020; Sekulova and Anguelovsk, 2017). Although, there is a concern that stakeholder engagement can slow down the realization process due to, among others, fragmented and competing interests (Raymond et al., 2017b), recent research indicates the opposite. Stakeholder participation can enhance the identification of ecosystem services, which ultimately can help to maximize the multi-functionality of solutions (Belmeziti et al., 2018; Dennis and James, 2016). The PHUSICOS project underlines that in all three case studies a novel stakeholder participatory processes was used that co-determined the actual design of the implemented NBS (IIASA, 2019).

Conversely, (Wamsler et al., 2020), in their empirical study, have found that public participation has rather hindered the sustainable outcome of NBS. It is argued that current institutions and power structures are inadequate to mainstream NBS fully and secure uptake into sectoral planning. In this sense, it requires more improved democratic governance models. Besides that, several barriers were found in the prior works that hinder public participation. Some pointed out that a public belief that attributes the NBS responsibility to governments prevents effective participation (Moskell et al., 2010). In addition, ineffective communication (Mensah et al., 2017; Moskell and Allred, 2013), conflicting stakeholders' interests and perspectives (Cousins, 2017; Ugolini et al., 2018) and bureaucratic hurdles (Liu and Jensen, 2018; Mattijssen et al., 2017) have been considered as barriers for public participation.

Therefore, the ThinkNature project concludes that policies should be established to not just support the collaboration and co-creation of NBS, but to also empower the public. So far, participation in the assessment, design, implementation, maintenance and monitoring/evaluation of NBS is predominantly taking place on a voluntary basis or within a specific project context. Therefore, a stronger enforcement of participatory processes is needed: "The legal and policy frameworks should provide specific guidelines to authorities, and practitioners and authorities should control the overall process for accomplishing this type of involvement" (Thinknature, 2019, p. 157).

3.2.6 There is a Need to Address and Overcome Political Barriers

One of the major barriers that hampers effective uptake of NBS is grounded in politics and power structures. Therefore, it needs to be carefully reflected on and taking into account when NBS shall be realised (Wamsler et al., 2017). Decision-makers can regard NBS as not being effective in reducing risks and therefore there will be a lack of political will to realise NBS, particularly at the municipal action level (Gulsrud et al., 2018; Liu and Jensen, 2018; Sarabi et al., 2020). It is argued by (Sarabi et al., 2020) that such political barriers are an underlying critical factor that influences all other governance barriers.

3.3 Outcomes of a Database Analysis on NBS Projects

In this section, we present the findings of an analysis of five databases documenting NBS projects. In total 408 case studies that implement NBS were identified and included in the analysis. Appendix A presents the methodology for the database analysis.

3.3.1 Relevance of Policies for the Realisation of NBS

According, to our analysis the European level is more influential in NBS implementation than any other policy level with 151 cases referencing at least one EU policy. This was followed by local policies (n=74 cases), regional policies (n=51) and national policies (n=46). The prevalence of EU policies in the implementation of local NBS projects implies the EU policies seems to be of high relevance to initiate and implement NSB projects. Although local policies were the second most common policy scale referenced, they occurred in 50% fewer cases than European policies, and the low incidence of meso-level policies suggests bottom up approaches are not widespread (Davis et al., 2018).

The European policy level was further categorised by specific EU policies and programmes (see Figure 10). The most common EU policy instrument was the Life+ programme (81 cases) followed by the Water Framework Directive (58) and Natura 2000 (47). The Life+ and Natura 2000 programmes are conservation-oriented instruments, whereas the WFD is focused mainly on water quality issues. The least common EU policies, occurring in less than 1% of the cases, were the SEA Directive and Green Infrastructure Strategy. Interestingly, the Green Infrastructure Strategy directly relates to a subset of NBS, yet it was the least referenced EU policy signifying a possibly underexploited policy avenue for NBS implementation.

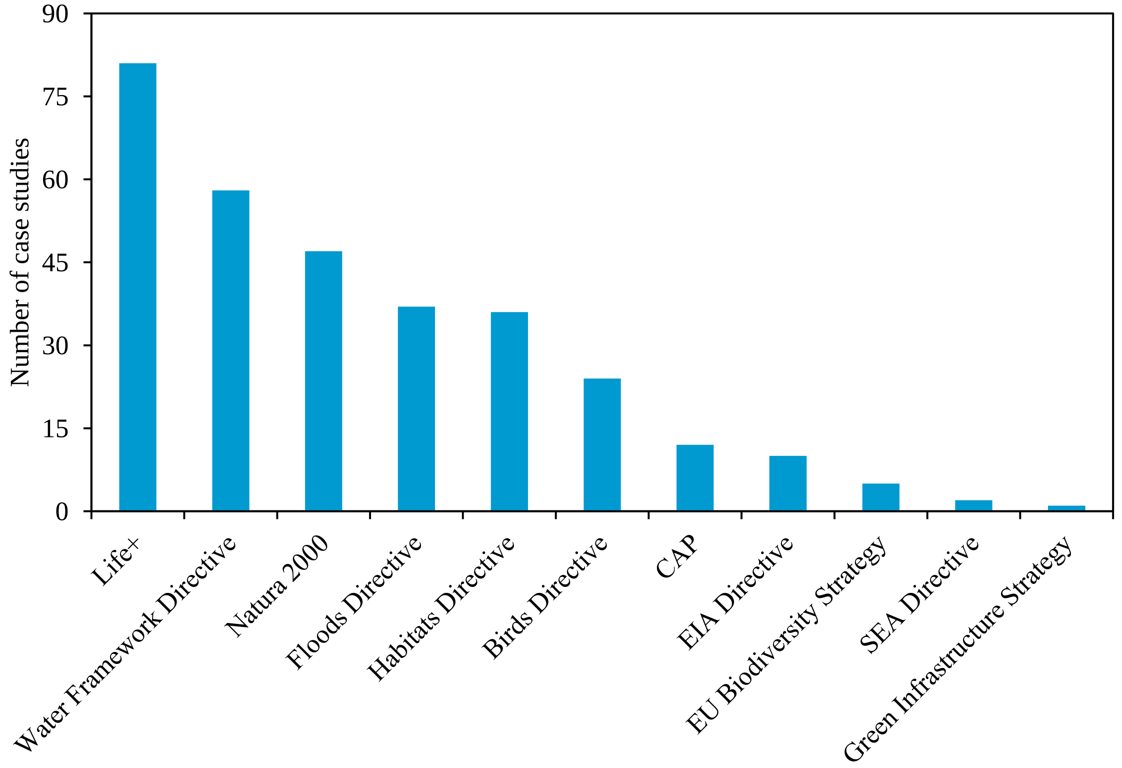
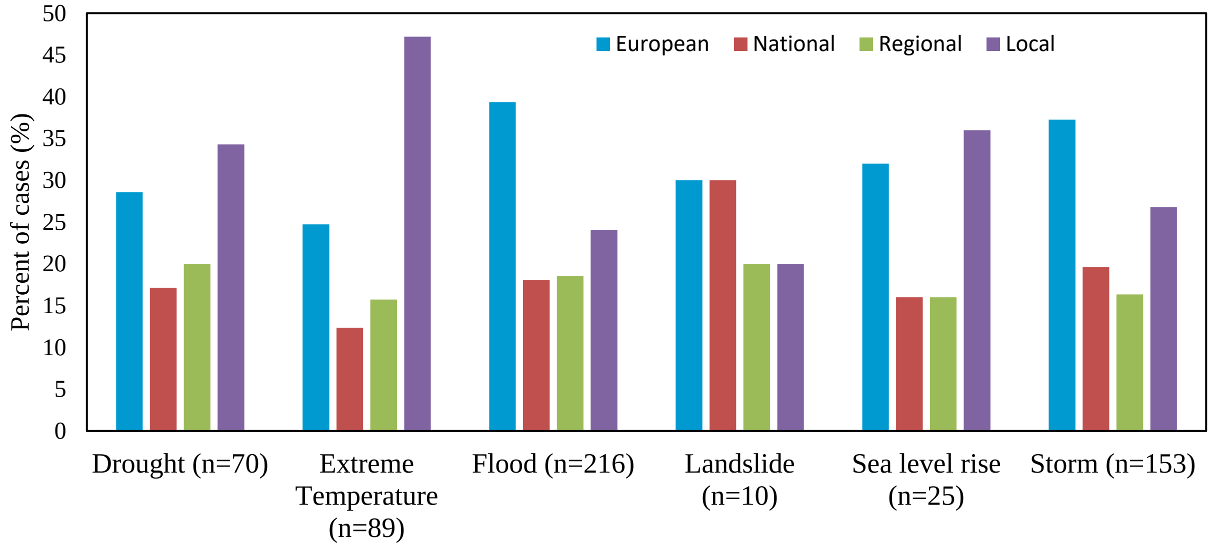


Figure 10 Frequency of EU policies.

3.3.2 *Policies and Risk/Hazards Addressed*

NBS cases that dealt with sea level rise, extreme temperature and drought risks were more likely to reference local policies, whereas cases that involved flood, sea level rise and storm risks were more likely to reference European policies (see Figure 11).

Concerning specific EU policies, the Water Framework Directive (WFD) was mostly referenced in projects that addressed droughts (28.2%), floods (25.6%) and storms (26.8%). Half of the cases that dealt with landslide risk (n=2) referenced the Floods Directive. The Life+ programme was the EU policy most mentioned in case studies involving extreme temperature risk (33.3%). Interestingly, the Habitats Directive had the strongest association with cases that addressed sea level rise (22.7%).



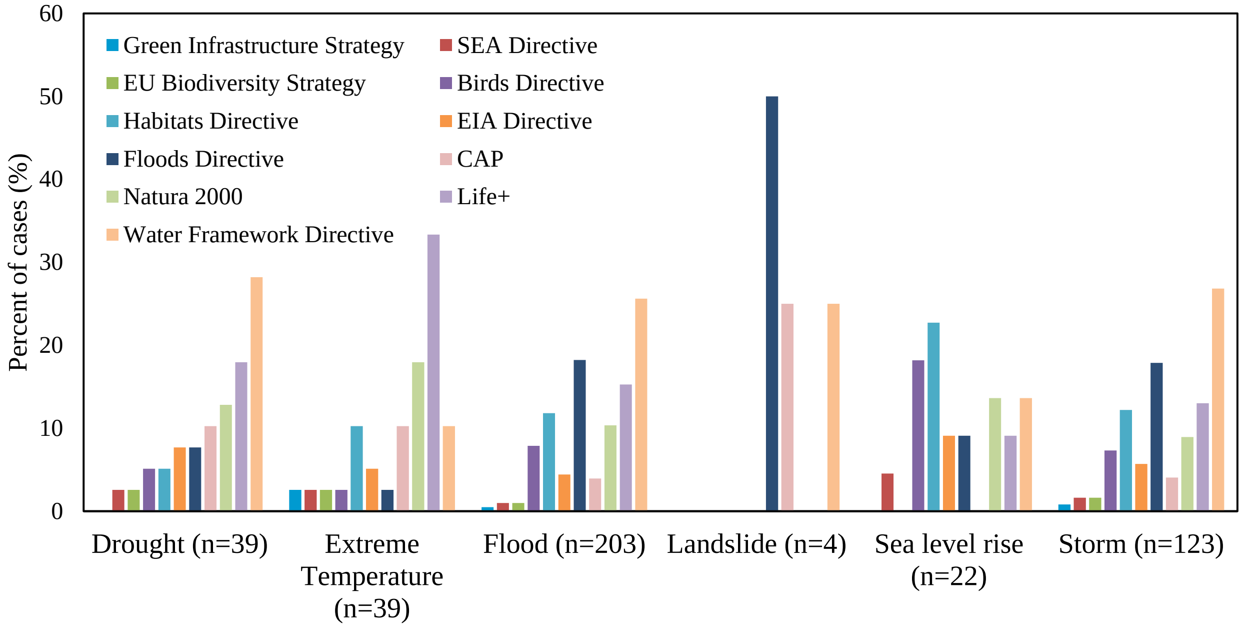


Figure 11 top: Percent coverage of policy level per risk type; bottom: Percent coverage per EU policy per risk type. Some projects mention more than one risk or EU policy type

3.3.3 *Policies and Challenges Addressed at Different Scales*

Cases addressing the challenges of Water Management, Coastal Resilience, Green Space Management, Economic Opportunities and Green Jobs, and Disaster Risk Reduction referenced European policies more than any other policy level (see Figure 12). Cases addressing the six other challenges (including all the dominantly social challenges) mentioned local level policies the most; local policies may be well situated to tackle social problems that are often context dependent. The regional and national policy levels were not the top referenced policy level for any of the challenges addressed.

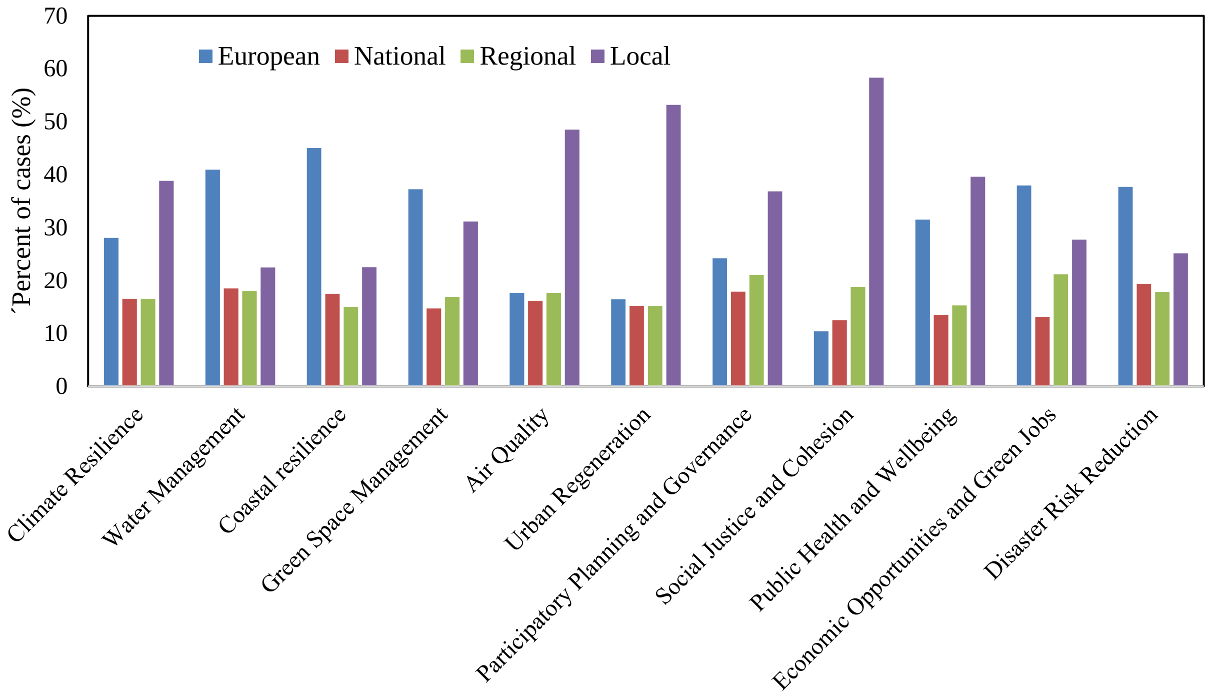


Figure 12 Percent coverage of policy levels per challenge addressed.

Further analysis on the coverage of specific EU policies across the challenges addressed shows a high level of association of the Water Framework Directive (WFD) with Water Management, Economic Opportunities and Green Jobs and Disaster Risk Reduction (see Table 2). The WFD was the most common EU policy used to address flood risk, which corresponds with the Water Management and Disaster Risk Reduction challenges. The Life+ programme was the most broadly used policy instrument; mentioned in over 15% of all challenges. Of note, the Floods Directive was the most referenced EU policy in NBS cases addressing Participatory Planning and Governance.

Table 2 Percent coverage of EU policies per challenge addressed.

	EIA Directive	SEA Directive	CAP	Life+	Green Infrastructure Strategy	EU Biodiversity Strategy	Floods Directive	Water Framework Directive	Natura 2000	Birds Directive	Habitats Directive
Climate Resilience	6.7	2.2	6.7	23.6	1.1	3.4	10.1	16.9	13.5	5.6	10.1
Water Management	4.1	0.9	4.6	15.5	0.5	0.9	16.9	25.6	9.1	8.7	13.2
Coastal resilience	5.4	2.7	0	16.2	0	2.7	8.1	18.9	13.5	13.5	18.9
Green Space Management	4.4	1.1	6.1	20.4	0.6	2.2	14.9	19.3	13.8	7.2	9.9
Air Quality	11.5	3.8	0	26.9	3.8	3.8	7.7	11.5	19.2	3.8	7.7
Urban Regeneration	18.2	4.5	4.5	31.8	0	4.5	4.5	13.6	18.2	0	0
Participatory Planning and Governance	8.6	1.7	1.7	17.2	1.7	1.7	22.4	20.7	13.8	3.4	6.9
Social Justice and Cohesion	16.7	8.3	0	25	8.3	0	16.7	16.7	8.3	0	0
Public Health and Wellbeing	6.3	1.6	4.8	23.8	1.6	4.8	7.9	23.8	12.7	4.8	7.9
Economic Opportunities and Green Jobs	4.1	0.8	6.5	17.1	0.8	2.4	13	23.6	10.6	8.1	13
Disaster Risk Reduction	4.7	1.2	3.6	14.2	0.6	1.2	19.5	26	8.9	7.7	12.4

3.3.4 Clustering of NBS Case Studies

To identify patterns and similarities across the 408 NBS case studies, hierarchical clustering was conducted. The purpose of cluster analysis is to place objects into groups suggested by the data, not defined a priori, so that the objects in a given cluster tend to be similar. For unsupervised hierarchical clustering, the dissimilarity matrix was calculated using Ward's minimum variance algorithm with the Binary metric. Out of the 63 original variables, 20 were removed from the analysis given their high number of missing values (e.g. only two projects mention the SEA directive). To define the appropriated number of clusters, the elbow method was used. Based on that, the most descriptive predictors were identified for each cluster. Furthermore, a principal component analysis (PCA) was used to plot the projects according to the first two principal components that explain the majority of the variance in the data (see Figure 13).

Policies at the European level Projects are cited mostly in cluster 1 (45.5%), whereas local policies are included in cluster 2 (68.2%, n=43) (Figure 13 and Table 3). Projects in cluster 2 tend to be costlier than those in cluster 1. With regard to the hazards addressed, NBS projects in cluster 1 deal mainly with flood hazards (n=117 or 61.3% of all flood projects), storms (65,5%, n=91) and sea level rise (65%, n=13) whereas cluster 2 is centred around droughts (78.9%, n=30) and extreme temperature (83.1%, n=49). NBS projects in cluster 1 addressed challenges such as water management (53.9%, n=118) and disaster risk reduction (63.7%, n=107). Conversely, projects in cluster 2 dealt mainly with climate resilience (65.5%, n=100) and green space management challenges (65.4%, n=109). Floods and storm-related projects (cluster 1) are positively loaded in the second dimension. Results suggest that drought and heatwave form a group that is negatively loaded in the second dimension and positively loaded in the first dimension, which describes 21.4 % of the variation in the data. Overall, cluster 3 is composed by projects where limited information on the societal challenges and hazards addressed is given.

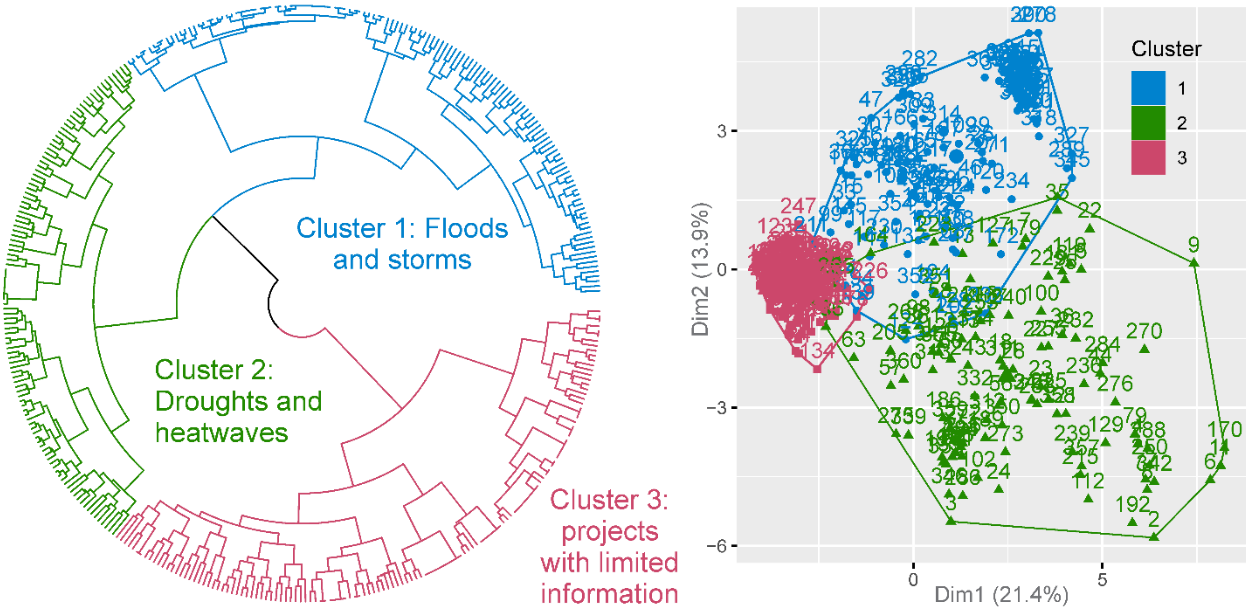


Figure 13 Left. Cluster dendogram obtained through hierarchical clustering of cases showing the similarity of the NBS projects. Right. Graph showing the clustered projects along the first two principal components

Table 3 Summary of clusters 1 and 2, showing their main dominant characteristics. Cluster 3 was not included as they usually do no provide enough information on the policies, hazards and/or challenges addressed

Cluster	Policies	Hazard	Societal challenges	NBS benefits
1	European, National, Regional	Flood, storm, sea level rise	Water management, Coastal resilience, disaster risk reduction	Flood risk reduction, groundwater management, landslide risk reduction, surface water quality, ecological status, recreational opportunities,
2	Local	Drought, extreme temperature	Climate resilience, green space management, air quality, urban regeneration, participatory planning, social justice, public health,	Drought management, education and awareness, cultural values, accessibility, community cohesion

3.4 Summary and Discussion on the Relevance of Policy Frameworks for the Realisation of NBS

In this chapter, we provided a synoptic overview on some of the key drivers and institutional barriers that support or hinders a more effective uptake of NBS. Based on a literature review (including insight derived from relevant EC-funded NBS projects) as well as an analysis of existing NBS data bases, some conclusions on the relevance of existing policy frameworks can be drawn.

Our analysis of existing data bases supports the observation that policy is a key factor supporting the uptake of NBS and that policy centric governance approaches are currently most prominent. With respect to the spatial scale, the European policy level is more influential on NBS implementation than any other policy level, followed closely by local level policies, regional and national policies. Furthermore, the most common EC policy instrument was the Life+ programme, followed by the Water Framework Directive, and Natura 2000. The Life+ and Natura 2000 programmes are conservation-oriented instruments, whereas the WFD is focused mainly on water quality issues but is also often mentioned in the context of disaster risk reduction.

The cluster analysis furthermore, revealed that local and supra-local policies seem to be differently relevant with respect to the hazards as well as societal challenges addressed. Based on the database analysis, local policies seem to be more relevant for reducing the risk from droughts and extreme temperature and for addressing the challenges of climate resilience, green space management, air quality, urban regeneration, participatory planning, social justice and public health. Supra-local and EC policies, on the other hand, seem to be more relevant for mitigating risks stemming from flood events, storms and sea level rise and for addressing challenges such as water management, coastal resilience and disaster risk reduction.

Finally, the literature review revealed that current policy frameworks encourage or support the maintenance of existing green and blue spaces and only to a lesser extent emphasize the restoration of ecosystems and their functions. This finding is indirectly supported by our analysis as the EC policies identified most often as relevant, are rather encouraging and/or supporting and less often directed towards restoring ecosystems and their functions. The literature review, furthermore revealed the benefits of a strong participatory approach in the realisation of NBS and this should therefore be encouraged more often by policy frameworks.

4 Development of a Synthesis Geodatabase for NBS

4.1 The Need for a Synthesis Geodatabase for NBS

The European Commission and other key actors are dedicated to bringing about innovative "sciences–policy–society" mechanisms, open consultations and knowledge-exchange platforms to engage society in improving the condition for implementation of NBS (Faivre et al., 2017).

On this basis, a number of NBS relevant repositories has been developed over the years. As such, a new NBS database is not desired, but a synthesis database that seek to harvest and synthesise data from multiple existing repositories can provide great value to the end-users.

This chapter first reviews existing NBS repositories, and then presents the RECONECT NBS synthesis geodatabase that gather information from existing repositories and present them in a user friendly way.

4.2 Analysis of the Existing Web Portals and Knowledge Platforms

Within RECONECT a thorough analysis of the existing NBS related repositories has been performed with the main objectives:

- To identify the key databases or sources of information that can be relevant for the RECONECT cases by delivering the state-of-the-art NBS cases and practical aspects of the NBS implementation
- To analyse the link between the science-policy-practice i.e. in which way these influence each other in the implementation of NBS

The first objective has been addressed in chapter 2, whereby the analysis related to the policy aspects and impacts on NBS is delivered in chapter 3. The remainder of this chapter focus on the analyses of the database structures.

The repositories have been analysed based on a set of criteria related to their content, terminology used, number of projects and countries involved, scale, funding or types of hydro-meteorological risks addressed. The full list of criteria is given in Appendix D. All platforms have been assessed on their main benefits and gaps in relation to the delivery of the NBS related information and its transferability to other projects focusing on NBS.

As the result of this analysis, the key web portals, networks and initiatives that at present address NBS at European, national and sub-national levels have been identified. These are given as OPPLA, BiodivERsA, BISE, ThinkNature, ClimateADAPT, Natural Water Retention Measures, Urban Nature Atlas, Disaster Risk Management Knowledge Centre, Natural Hazards – Nature Based Solutions, Nature-based Solutions Initiative, weADAPT, Nature of Cities, ClimateScan, Partnership for Environment and Disaster Risk Reduction (PEDRR) and PANORAMA (Ruangpan et al., 2020).

For the detailed analyses, only the platforms that contain both knowledge and practical relevance to existing NBS projects have been considered. An overview of these platforms with their main features is given in Table 4.

Table 4 An overview of selected platforms with some of their main features (Ruangpan et al., 2020).

Name	References/ Website	Terminology used	Scale level	Funded by	Purpose
OPPLA	https://oppla.eu	Nature-Based Solution, Natural capital, Ecosystem services	Local to global	FP7 (EC)	A new knowledge marketplace - EU repository of NBS; a place where the latest thinking on ecosystem services, natural capital and NBS is brought together.
ClimateADAPT	https://climate-adapt.eea.europa.eu/	EbA, Nature-Based Solution, GI	Europe	EC, EEA	A platform that supports Europe in adapting to climate change by helping users to access and share data and information relevant for CCIVA.
Natural Water Retention Measures	http://nwrm.eu/	Natural water retention measures	Europe	EC	A platform that gathers information on NWRM at EU level.
Urban Nature Atlas	https://naturvation.eu/atlas	Nature-Based Solution	Europe	Horizon 2020 (EC)	A platform that contains around 1000 examples of NBS from across 100 European cities.
Natural Hazards – Nature Based Solutions	https://naturebasedsolutions.org	Nature-Based Solution	Global	The World Bank	A project map that provides a list of nature-based projects that are sortable by implementing organisation, targeted hazard, and type of NBS, geographic location, cost, benefits, and more.
ClimateScan	https://climatescan.nl	Blue-Green Infrastructures	Global	EC	Global online tool which acts as a guide for projects and initiatives climate proofing and climate adaptation around the world.

A short summary of the included repositories is given in the following.

4.2.1 *OPPLA (https://oppla.eu)*

OPPLA is one of the key repositories at the EU level and a new knowledge marketplace. It contains the relevant technical information about the projects also including the lessons learned and the transferability of results.

The main advantage of this platform is that all scales are addressed (global, continental, sub-continental, National, Subnational, Local) and availability of publications for some projects. Also, this platform has been recognised as the EC platform for the visualisation of NBS related projects and is likely to grow with high quality NBS projects. The assessed deficiency are the heterogeneity in the presentation of the projects with some of the key large-scale NBS projects fully missing (e.g. the room for the river programme). Further, Australia, China and USA, although all having high profile NBS related strategies and projects (e.g. sponge cities in China) are still underrepresented in OPPLA. Figure 14 show the layout of OPPLA.

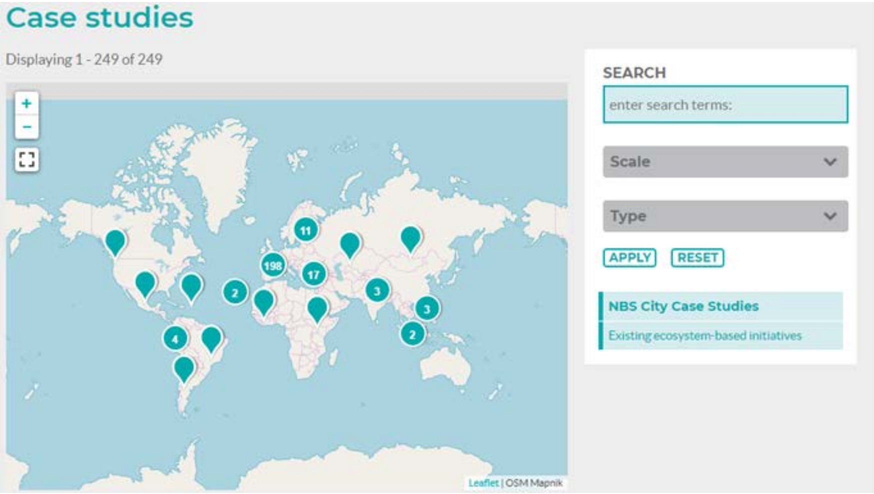


Figure 14 The page on case studies in the OPPLA platform.

4.2.2 *ClimateADAPT (https://climate-adapt.eea.europa.eu/)*

This is a mainly EU oriented platform that supports Europe in adapting to climate change by helping users to access and share data and information. It contains descriptions of case studies, but also delivers other relevant information and documents such as publication and reports, relevant research projects, tools or adaptation options. The main benefits of this platform are that it addresses all types of climate impacts (extreme temperatures, flooding, droughts, water scarcity, storms, sea level rise, ice and snow) and its interactive user interface in which information can be shown in country or transnational regions by clicking on maps. All case studies and adaptation options are provided in the same format. The contained database has selectable options and search functions. The main disadvantages are its exclusive focus on Europe and the lack of focus on NBS (the platform provides a broad range of information regarding climate adaptation in Europe but does not emphasize NBS). Figure 15 show the layout of ClimateADAPT.

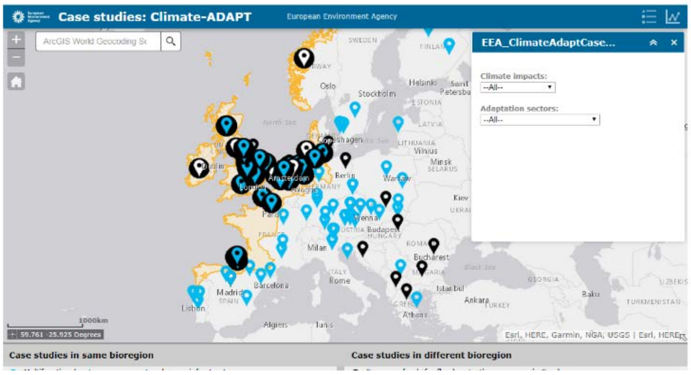


Figure 15 The ClimateADAPT Platform.

4.2.3 *Natural Water Retention Measures (NWRM) (http://nwrm.eu/)*

This platform collates information on NWRM at EU level. The main benefits delivered within this platform is a clear structure (catalogue like) in which different measures are assigned to different domains (such as urban, agriculture, forest and hydro-morphology) and clearly presented. Also, large-scale measures are included e.g. Re-naturalization of polder areas or natural restoration of rivers are also considered. The main disadvantage of the platform is its exclusive focus on Europe and the missing solutions for coastal flooding. Figure 16 show the catalogue of measures available in NWRM.

Figure 16 The catalogue of measures available at Natural Water Retention Measures.

4.2.4 Urban Nature Atlas (https://naturvation.eu/atlas)

This platform contains around 1000 examples of Nature-Based Solutions from across 100 European cities. The focus is on rivers, urban and coastal areas. The measures implemented are presented in a structured way including costs and benefits, but also include the monitoring approach and expected impacts and governance, which is a major benefits of this platform. However, this platform has a very strict urban focus and as such has much more narrow focus than the RECONECT demonstrators and collaborators. Further, only limited information about the design and construction of the implemented NBS is available. Figure 17 show the layout of the Urban Nature Atlas.

Figure 17 The overview of the cases in Urban Nature Atlas with the search engine.

4.2.5 Natural Hazards – Nature Based Solutions (https://naturebasedsolutions.org/)

This platform provides a list of NBS projects that are sortable by implementing organisation, targeted hazard, type of NBS, geographic location, and more. This is a very well organised database where some of the projects funded by the World Bank also gives indications on the costs and benefits of the projects. In order to relate them to the potential hazards, the hazard maps of the hydro meteorological risks addressed are available. However, some major projects and strategies are missing, such as the sponge cities. The NBS presented are limited to mountainous areas or for flash floods. Figure 18 show the layout of the Nature Based Solutions Platform.

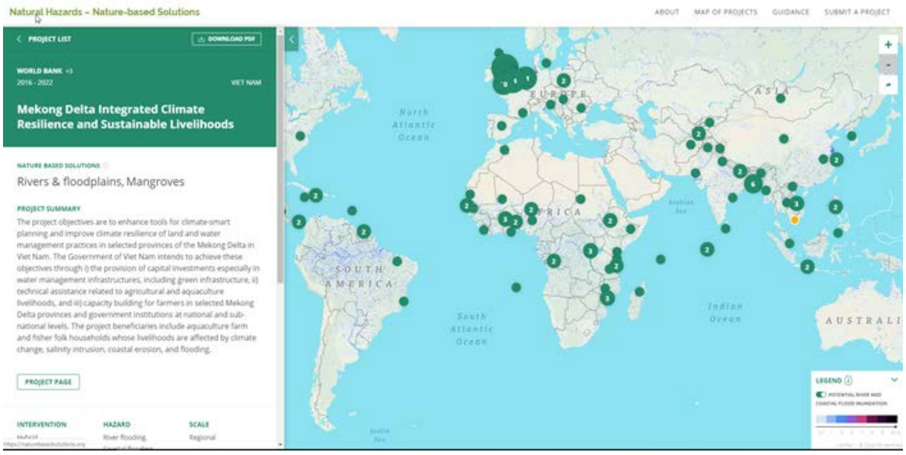


Figure 18 Geographic spread of the projects available in the Nature Based Solutions Platform.

4.2.6 *Climatescan (https://climatescan.nl)*

A platform developed by a research group from the Centre of Research & Innovation for Built Environment (Hanze University of Applied Sciences Groningen). It is presented as an interactive online map application that provides an easy-to-access database of international project information and case studies. Originally the platform has been dedicated to the urban resilience, however during the RECONECT lifetime, it extended its original purpose to contain the NBS cases from rural and periurban areas.

The main advantage of this platform is its flexibility. Currently, all the data points are categorised into 20 sub-groups. Users of climatescan can create their own climate adaptation categories and upload projects. Most of the categories relate to sustainable urban drainage systems (SUDS) and Best Management Practices (BMPs). The tool is used in several international workshops and RECONECT demonstrator visits and serves the needs of different stakeholders.

Climatescan is used in several other international projects other than RECONECT (e.g. Inovations for eXtreme Climatic EventS and WaterCo-Governance: INXCES and WaterCoG) and international knowledge exchange climate change workshops and fieldtrips, serving the needs of different stakeholders participating in those workshops (Boogaard et al., 2017).

The main disadvantage is the lack of structure and focus on (large-scale) NBS: Most of the projects are only very briefly presented. Figure 19 shows the layout of Climatescan.

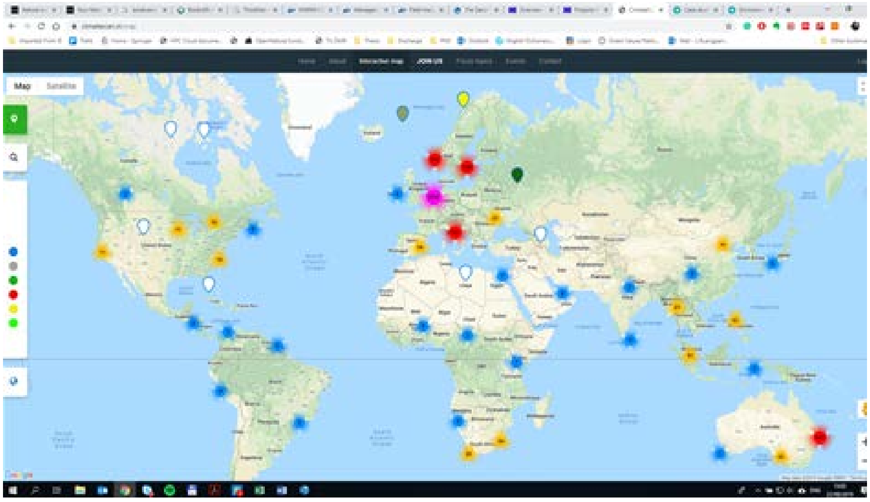


Figure 19 Overview of the measures available in Climatescan.

4.2.7 *Summary of the Findings*

The presented platforms address similar topics and issues, but differ in a number of aspects such as scope, scale, level of detail and format. This makes it difficult to analyse and extract and compare the relevant information from them. The developed RECONECT NBS synthesis database addresses exactly this issue as described in the rest of this chapter.

4.3 RECONECT NBS Synthesis Database

The main objective of the RECONECT geodatabase is to provide a structured access to the NBS related knowledge from existing repositories.

In the first instance, the RECONECT Database will address the existing knowledge contained in the online platforms listed in Table 4 by storing the information available there in a structured way and visualizing this information spatially. The authors are aware of that several projects are working on initiatives that will results in further relevant repositories and the synthesis database can be expanded when such are available. The developed structure of the database is provided in Appendix C.

Moreover, the database will be directly enhanced by the examples and lessons learned from the RECONECT demonstrator and collaborator sites. Furthermore, a dialog will be initiated with the RECONECT sister projects OPERANDUM (https://www.operandum-project.eu) and PHUSICOS (https://phusicos.eu) projects with the intent of exploring the option of producing one joint database with the needed information from all three projects.

Additional specific feature of the RECONECT database is reflected in the collection of the lead user solutions and the associated innovation that will be systematically analysed in RECONECT (see Chapter 5). These solutions are, as a rule, not available in any or the existing repositories, but can be a valuable resource and information for the agencies or institutions implementing NBS.

The RECONECT database will address two main target groups:

- The project partners in particular the Demonstrators, who are currently implementing or monitoring their NBS , so as the Collaborators that seek inspiration and advice to start developing their own NBS strategies. The defined structure and the visualisation tool would enable them efficiently performing gap analyses, but would also facilitate searching for the projects of their interest.
- The wider group of scientists, practitioners and decision makers beyond RECONECT: once finished, the database will be made public and/or will provide links and inputs to the existing main repositories as presented in section 4.1., mainly targeting the OPPLA platform.

A geographic component was added to the development of the database allowing the user to search and visualize NBS related information across the selected platforms in a clearer and more intuitive way.

The geodatabase was implemented using the ESRI software, more specifically a file geodatabase was created using ArcGIS Desktop version 10.5 under Advance level of licensing. However, the maintenance and use of the file geodatabase can be done using any 10.x version with any level of license of the ESRI software. The steps for creating, implementing, and using the database are summarized as follows:

1) Requirement analysis
   a) Definition of objectives,
   b) Definition of functional and spatial requirements,
   c) Definition of data requirements.
2) Database design
   a) Data dictionary,
   b) Logical/Geodatabase model.
3) Geodatabase Implementation
   a) Geodatabase creation,
   b) Data upload,
   c) How to use it,
   d) Summary map.

The detailed requirements analysis is provided in Appendix A and the design and implementation in Appendix C.

4.3.1 *Suggestions for Usage of RECONECT NBS Synthesis Geodatabase*

The current iteration of the synthesis geodatabase is an internal RECONECT tool and that will be rolled out to the Demonstrators and Collaborators. In the future it will be explored if it is feasible to publish a public geodatabase, possibly in cooperation with the sister projects to RECONECT: OPERANDUM and PHUSICOS.

To use the geodatabase, one needs to locate the file NBS_geodatabase.mxd. This project uploads all the necessary data on ArcMap (Figure 20) and the information stored in the database as well as the connections between the different components can be directly be used. In Figure 21 an example is presented for when the user selects the country Brazil. In this example, Brazil has information reported in two platforms, i.e., ClimateScan and NH-NBS. To display information on the platforms that address Brazilian NBS projects, the platform can be selected and the related information is made accessible. Figure 22 represents a preliminary overview of information contained in the six included platforms.

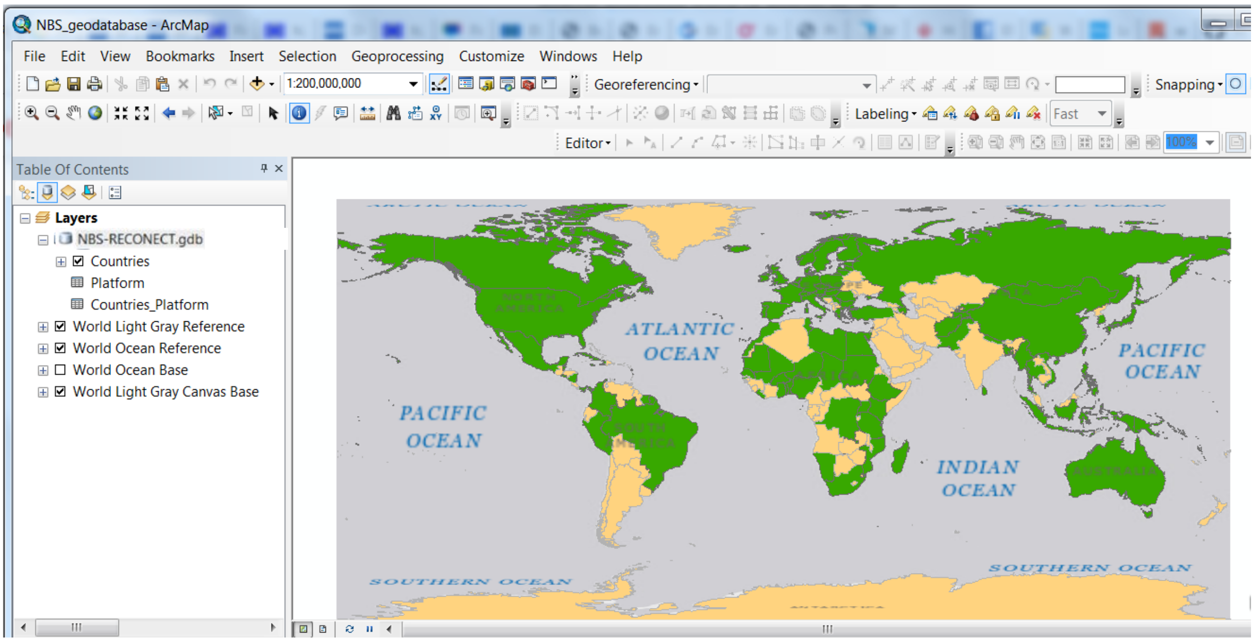


Figure 20 Screenshot of the NBS_geodatabase for the RECONECT project.

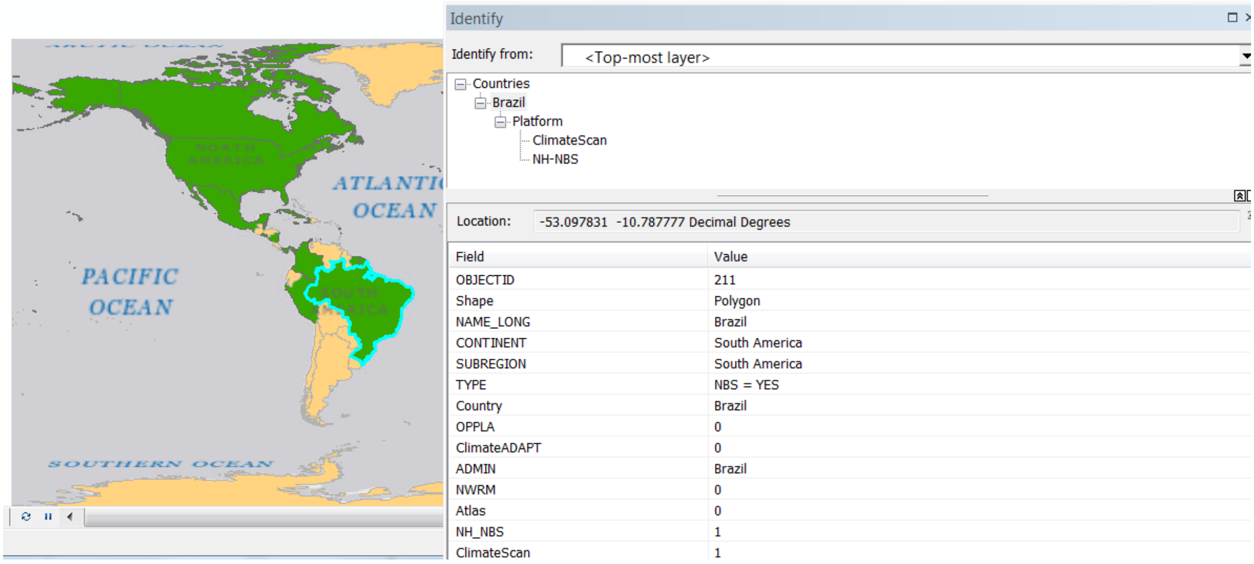


Figure 21 Screenshot of the usage of the geodatabase to query information (Brazil as an example).

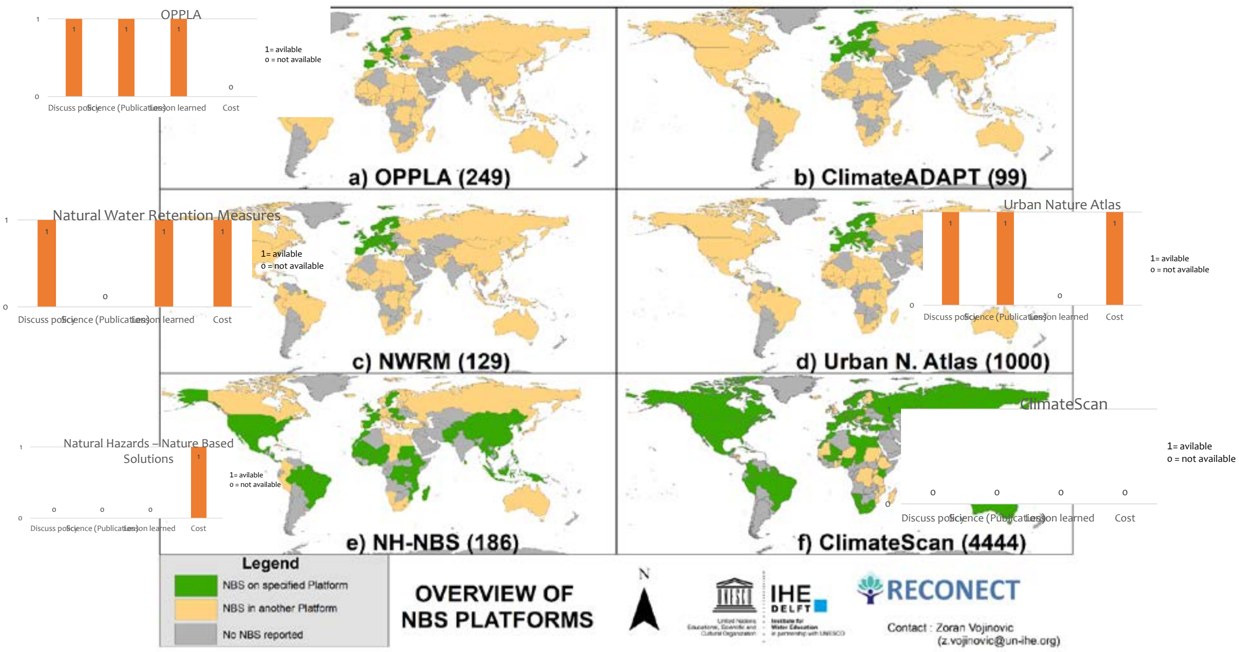


Figure 22 Preliminary overview of information contained in six platforms. The bar charts represent information related to policy, science, lessons learned and costs.

In the next step, RECONECT will make available this information to the first target user group being the project partners In the further step, the NBS demonstrated in RECONECT will feed into this database so as the solutions collected by the means of the lead user analysis (see Chapter 5).

5 Pursuing NBS Innovation through Lead Users

As highlighted in Chapter 4, despite that many platforms contain information and projects from different parts of the world, the innovation and solutions that are happening outside of official projects or are an initiative of individuals rather than institutions are often kept undocumented. However, this is a valuable source of information as those solutions may be relevant for the upscaling in the region due to similar contexts and needs within one region, rather than merely importing the technologies and solutions from other parts of the world

RECONECT addressed this scattered way of reporting of NBS and their low visibility in the international context by adopting and enhancing the Lead User Method.

The Lead User Method applied in the RECONECT enables to find, document and create visibility of the tested and proven lead user innovations related to NBS; these have been developed by the people themselves while facing hydro-meteorological risks. The method is a step-by-step process to identify user innovators, and, in the end, to find ways to up-scale the most valuable innovations and to make them generally available for those in need. Therefore this chapter is composed in a way so to:

- discuss why it is valuable to focus on lead users and lead user innovation,
- explain the Lead User Method and how it can be adapted to respond to the general aims of the RECONECT project, while also
- providing examples of lead user innovations targeting hydro-meteorological risks that could be expected as a result of the Lead User Method for NBS.

5.1 Scientific Background

5.1.1 Lead Users

Producers develop innovative goods and services in order to sell them to customers, consequently following benefit-motivated targets. (von Hippel, 2005). In contrast, users innovate when they cannot find suitable products or solutions in the market that satisfy their needs. Those user innovations are frequently developed by so-called lead users. Lead users are characterized by two essential aspects. (Lüthje and Herstatt, 2004):

- Lead Users face new needs of the market and do so significantly earlier than the majority of the customers in market segment (capability).
- Lead Users profit strongly from innovations that provide a solution to those needs (motivation).

Additionally, lead users very often possess a higher (technical) expertise, have high use experience in their field and are well connected within their community (Franke et al., 2006). This means that in a broader sense lead users are characterized by:

- being more advanced in terms of perceiving their problems and needs compared to the majority of users,
- being usually tremendously hindered in doing their job due to missing adequate products or services,
- being (thus) in a position in which an innovation could be tremendously beneficial for them,
- being actively innovative in order to overcome this barrier which producers do not see yet.

Lead users develop product ideas or even first prototypes when commercial products do not yet exist. Thus, they offer essential insights for the development of innovative and particularly customer-oriented products and services. (Herstatt and von Hippel, 1992). Early adopters, in contrast, are the first to buy an innovation that has been commercialized already. Figure 23 shows a leading position of lead users in comparison with other types of users (Churchill et al., 2009).

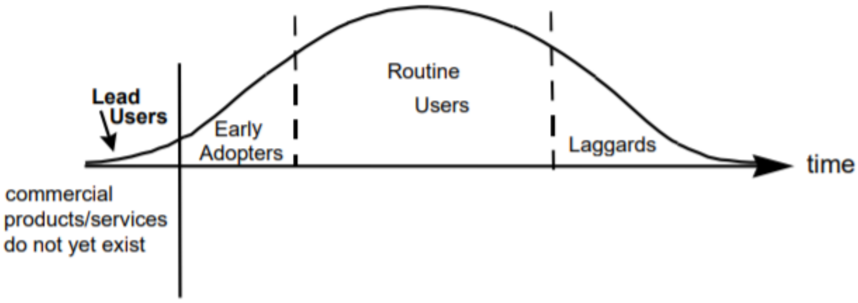


Figure 23 Positioning of lead users in product innovation diffusion curve (Churchill et al., 2009).

Lead users have needs that are ahead of all other user groups and this leads to the new product development in a given market (Churchill et al., 2009). Since lead users' needs are representative for the market, other users are usually impressed by the innovation and are eager to pay for the solution as well. Well-known examples of lead user innovations are Snowboards, Skateboards, Tip-Ex or the coffee filter. Such user-centric products and solutions created by lead users can be found in most sectors. However, even though the research shows that lead users collectively generate massive amounts of product innovation (von Hippel, 2011), to this day there is no database developed to easily find these kind of solutions, that are created by the consumers themselves.

5.1.2 Lead User Method

In order to continuously and actively search for the lead users in a structured way, the Lead User Method was developed. This process is divided into four important steps (see Figure 24) (Lüthje and Herstatt, 2004):

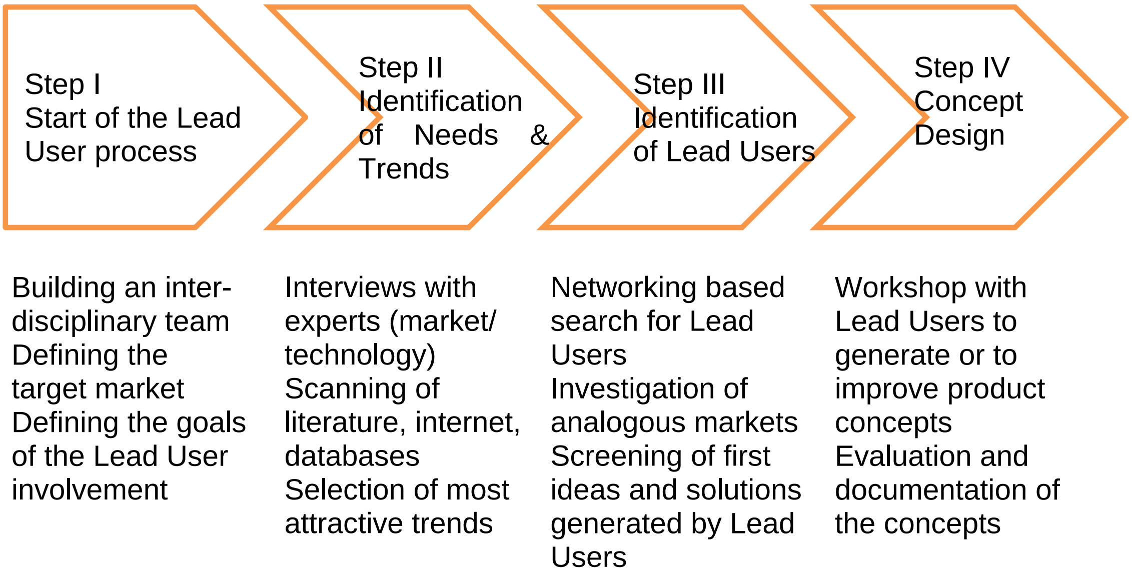


Figure 24 The general process of the Lead User Method (Lüthje and Herstatt, 2004).

However, in relation to NBS in particular, the process would have to be slightly adapted in order to fit the needs of the project partners and to better correspond to the underlying question.

5.2 Methodology: Lead User Identification for NBS

To summarize the description above, lead users are defined as individuals or organizations suffering from unsolved problems and/or having strong needs while having no access to appropriate solutions. Lead users therefore invest their time and resources to develop own solutions, although time and resources are often limited. If such frugal solutions are well perceived by others facing the same problems, they have the potential to become general solutions and thereby help many others.

Therefore, the Lead User Method in the frames of the RECONECT project should be applied with the aim to identify NBS to reduce hydro-meteorological risks developed by lead users that as concepts for new products or services have strong market opportunities, applicability and transferability.

As mentioned before, the process of the Lead User Method is organized around the four steps:

- Step I: Start of the lead user process;
- Step II: Identification of needs and trends;
- Step III: Identification of lead users; and
- Step IV: Concept design

Each step is defined by a core set of activities that are essential to carrying out a thorough analysis. For this project the activities within the process have to be slightly adapted responding to the aforementioned aim for the Lead User Method (see Figure 25).

Step I Start of the Lead User process	Step II Identification of Needs & Trends	Step III Identification of Lead Users	Step IV Concept Design
Building an interdisciplinary core team of members from partner organizations involved in WP1: TUHH, IHE, TAUW, UIBK, DTU, FHH, UNEXE, MONASH MALAYSIA, Amphi, UNBELGR, BDCA, UNSA, CNR, UFZ, STRANE, EAWAG, SEI Defining the project scope: Type of hydro-meteorological hazard Phase Outcome Technology Affected area Geographic area Subject to protect Local origin of idea Defining the goals of the Lead User involvement Initial brainstorming on trends and drivers of hydro-meteorological risks in kick-off presentation	Identifying experts in the field of hydro-meteorological risks' reduction worldwide, with a focus on experts in the area of the selected type of hydro-meteorological hazard/-s and experts within the RECONECT Consortium Development of questionnaire Survey of experts Scanning of literature, internet, databases Selection of most relevant trends and drivers of selected of hydro-meteorological hazard/-s	Identification of Lead Users that are either directly affected by hydro-meteorological hazard/-s or have solved an analogous problem by applying different techniques: Screening Pyramiding/Networking Desk research Field visit or contact with identified innovators (if possible)	Screening and rating of potential Lead Users and their concepts (by conducting a meeting where all innovations will be jointly screened by the core team, if possible) If possible: Joint workshop/ conference with selected Lead Users Selection of most promising Lead Users and their concepts for further development/ scaling

Figure 25 The process of the Lead User Method for NBS to reduce hydro-meteorological risks.

5.2.1 *Step I*

In the first step an interdisciplinary core team is built with members of all project partners and an extended team including all stakeholders and partners who are working on NBS to reduce hydro-meteorological risks. The core team has to decide on the final target of the project as well as on the goals for the lead user involvement.

This initial phase of the Lead User Method plays a crucial role for the success in identifying the solutions that are actually relevant for the project. The first and the most important step is aimed at opening the solution space and collaboratively deciding:

- What ideas do we want to identify by applying the Lead User Method?;
- Are we looking at innovations targeting one kind of hydro-meteorological hazard or all kinds of hazards?;
- Do we want to focus on the location (urban or rural areas)?;
- What is the regional focus of our research?

As a result the questions help to define the project scope.

Table 5 Elements to define the project scope,

Elements						
Type of hydro-meteorolo-gical hazard	Floods	Droughts	Hurricanes or/and tornadoes	Landslides or/and mudslides	Heavy rainfall/ snowfall	Heat-waves
Phase	Medium and long-term hydro-meteorolo-gical risk prevention	Short-time hydro-meteorologi-cal risk prevention (Preparedness)	During the time of hydro-meteorologi-cal risk event	After hydro-meteorological risk event		
Outcome	Nature-based solution	Monitoring device for nature-based solution	Service	Physical product	Inventions / concepts	App / IT
Technology	Fixed	De-mountable / re-usable	Temporary / modular	Sustainable		
Affected area	Urban	Semi-urban	Rural			
Geographic area	Mainland	Mainland shore	Island	River / inland		
Subject to protect	Humans	Animals / farms	Infrastructure	Industry	Cultural assets	Housing
Local origin of idea	Particular country	Europe	Globally			

After deciding for the type of hydro-meteorological hazard the research will focus on, it is also relevant to think of a phase of the hydro-meteorological risk event that the innovations (and in this case – innovations as NBS) should be targeting. NBS in the area of hydro-meteorological risks can be clustered into four different phases:

1. NBS for medium and long-term hydro-meteorological risk prevention,
2. NBS for short-time hydro-meteorological risk prevention,
3. NBS at the time when the hydro-meteorologically risky events appear and
4. NBS used after the hydro-meteorologically risky events.

The project partners have to decide if the scope of the analysis is on selected phases or on the entire process described above.

5.2.2 Step II

In this step trends are scouted and available information (literature, online-communities, expert knowledge) is analysed. Such trends might include the increased frequency of hydro-meteorological hazards, regional occurrence of hydro-meteorological hazards, infrastructure damages and upcoming health issues. It is also important to look at the measures and standard procedures currently applied by local communities and authorities to cope with hydro-meteorological risks and associated problems. This part of the study is carried out via desk research and, if possible, via on-site visits by the local partners in given areas. Further, experts in hydro-meteorological hazards and NBS should be consulted. The most relevant trends and information are selected in a joint meeting of the core team.

5.2.3 Step III

The goal of the third step is to identify lead users and their NBS targeting hydro-meteorological risks. The aim is to detect individuals, communities and organizations who were innovating because they are directly affected by hydro-meteorological hazards and/or with analogous important issues identified by the core team. The main focus should be on lead users in the partner countries and their regions, but using the established network a closer look should also be given at other areas in the world that frequently have and suffer from selected hydro-meteorological hazards.

Another important way that bares a big potential to identify NBS targeting hydro-meteorological risks is to take a closer look at what we call *analogous* lead users. These are lead users innovating in other but still relevant (analogous) fields or markets. For example, in a preceding project the Institute for Technology and Innovation Management from Hamburg University of Technology has gained experience in identifying analogous lead users innovating in combination with natural disasters: So-called “storm chasers” who track hurricanes were consulted during a research project together with a telecommunication network provider to develop innovative IT-solutions (Herstatt et al., 2006).

If possible, the third step of the Lead User Method is separates into two parts: First, a preparation phase where the desk research is conducted, and second, on-site visits in partner countries where the innovators are visited.

Depending on the scope of the project, different techniques like *networking* or *pyramiding*[1] (von Hippel et al., 2009) could be applied during the preparation phase to identify the lead users. The core team should closely work together with their local partners and try to involve local authorities as well.

Afterwards and if possible, a team of two or three core team members should visit the innovators. They should thoroughly analyse the innovations on site and prepare a sound documentation of all relevant innovations as NBS targeting hydro-meteorological risks.

5.2.4 Step IV

In the last step a workshop should be conducted where all innovations would be jointly screened by the core team. Afterwards, the most promising innovations should be selected to be presented during the partner meeting of the RECONECT project.

Additionally, it would be beneficial to invite the innovators to the partner meeting of the RECONECT project and conduct another workshop to develop the most promising innovations even further.

Such a study based on the Lead User Method enables to find out how individuals and communities innovate using NBS in order to better cope with the challenges and problems from hydro-meteorological extremes. Together the RECONECT partners aim to discover people and/or organizations who have already developed workable solutions for their own needs, but who, for different reasons, could not yet diffuse those inventions to others.

5.3 Examples of Lead User innovations in relation to NBS

With such research based on the Lead User Method two kinds of innovations are expected to be identified:

- An entrepreneurial track, i.e. concepts can be transferred to a viable business.
- A grassroots track, i.e. concepts are diffused peer-to-peer among local communities.

Both kinds are equally interesting to be explored and evaluated for their potential for applicability, transferability and scalability in order to build the knowledge base of the innovations as NBS for hydro-meteorological risk reduction developed by the people and communities to benefit people. Table 6 provides examples of lead user innovations related to NBS addressing different hydro-meteorological risks.

The solutions developed by Lead Users identified in RECONECT will feed into the RECONECT Geodatabase.

[1] Pyramiding is a search process based upon the idea that people with a strong interest in a topic or field tend to know people more expert than themselves.

Table 6 Examples of Lead User innovations in relation to NBS.

Solution	Hydro-meteorolo-gical risk	Description	Visual
Monitoring device for hydro-meteorolo-gical risk reduction	Landslides	**Sipendil** is a low-cost rain gauging device that acts as an early warning system for landslides. It was developed by a researcher from UGM Yogyakarta after he witnessed a landslide. The device is already used in several villages to warn inhabitants about massive rainfall.	 Picture from the Institute for Technology and Innovation Management, TUHH
Nature-based device for hydro-meteorolo-gical risk reduction	Droughts	**Airdrop** is a device developed by a university student touched by the consequences that one of the worst droughts in Australia had on orange farmers, who for years were suffering from mounting debts and failing crops. The self-powering device delivers moisture to the soil by feeding the humid air from the atmosphere back underground to the nearby plants. By employing a system that enabled to provide regular moisture to plants, being grown in even the driest places, Airdrop ensured a worldwide attention and had received several awards.	 Picture from www.dyson.co.uk
Community nature-based solution for hydro-meteorolo-gical risk reduction	Floods	A **living weir** is a nature-based structure made out of sandbags, bamboo and banyan trees designed to change the velocity of a river. This result not only in higher flood resilience but also in an increase in groundwater levels, a higher biodiversity and a sediment trap. The concept was introduced by a local community in Thailand, and is a nature-based solution that was built on local knowledge and with local materials.	 Picture from The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)

Nature-based solution for hydro-meteorolo-gical risk reduction	Floods	**Elevated houses** in Pakistani village raised after a wheat farmer living in this remote village had to rebuilt his house for several times due to recurring inundation. At one point, after losing his house again, he decided to adapt and rebuilt it on a raised dirt platform with surrounding eucalyptus trees. This new housing concept did not take long to be adopted by locals and transfuse to nearby villages. As a result less people have to migrate from the area as a consequence of a flood.	 Picture from www.braced.org

6 Summary and Outlook

6.1 Summary - Linking Science Policy and Practice

The current review if state-of-the-art clearly indicate that NBS offer valuable solutions for hazard risk reduction across water, nature, and people objectives. Incorporating NBS enable construction of more resilient communities, where citizens not only experience fewer damages, but also gain the added benefits from NBS with improved wellbeing for humans as well as improved terrestrial and aquatic environments.

The knowledge about NBS and its sister concepts is spread across the world, but is having different framings or brandings in different countries (e.g. Water Sensitive Urban Design in Australia, Sponge Cities in China, SUDS in Europe, LIDs and BMPs in USA, eco-engineering in Europe and USA). This especially applies to the large-scale NBS. While they may have been implemented in practice and have been the focus of research in the past years and decades; they have not been explicitly framed as nature based solution (e.g. the Dutch Programme Room for the River or controlled flooding of green spaces along the river Elbe to avoid flooding of urban areas), nor do the examples point towards one dominating framework or approach of analysis towards design or upscaling of the individual applications. The challenge of this report has been to identify good examples and concepts and address them in the context of NBS and their potential to improve the water-nature-people dimensions as defined in RECONECT. The review thus confirms that there is a need for further promotion of how to mainstream selection of relevant NBS for typical problems, how to assess and compare the suitability of different NBS elements in a given context, and how to design an overall large-scale NBS based on several NBS elements.

In terms of policy, there is a discrepancy between the recommendations from research to deploy a bottom-up approach for successful NBS implementation and the reality, where EU level policies is most often mentioned in implemented NBS projects followed closely by local level policies and plans. Regional and national policies are very seldom mentioned. Also, a limited number of EU policies (Life+, Water Framework Directive and Natura 2000) were reported as the main drivers of the implementation of NBS in any of the analysed case studies, as presented in Chapter 3. A cluster analysis showed that local policies seem to be more relevant for reducing the risk from droughts and extreme temperature and for addressing the challenges of climate resilience, green space management, air quality, urban regeneration, participatory planning, social justice and public health. Contrarily, EU policies seem to be more relevant for mitigating risks stemming from flood events, storms and sea level rise and for addressing challenges such as water management, coastal resilience and disaster risk reduction.

In order to bridge NBS implementation gaps, innovation can play a significant role. As an important first step the existing innovative, locally attuned solutions, which are not documented, should be identified and made available to a wider audience. They can serve as a prototypes or inspiration for practitioners and communities. RECONECT approaches this need by enhancing and deploying the existing Lead User Method, which will identify NBS related methods, tools of devices and provide them to the RECONECT Demonstrators and Collaborators.

The RECONECT NBS synthesis geodatabase has been developed as a “one-stop shop” solution, referencing and spatially visualising the existing information available in key web repositories. It enables focused search of the required information and as such it facilitates the conduction of gap analyses related to the existing knowledge and practices. Moreover, RECONECT adds value to this, by presenting the solutions implemented in the RECONECT demonstrators and envisaged in the collaborator sites. Further, the results of the Lead User Analysis, being the locally attuned NBS related innovative solutions, will feed into the RECONECT geodatabase. This will be further addressed in RECONECT Deliverable D1.4. Development of this synthesis database can facilitate a more efficient analysis of the existing links between knowledge and practice with policies and as such contribute to a better implementation of NBS.

6.2 Outlook - Gaps, Challenges and Opportunities

Research, implementation, and practice on NBS for hydro-meteorological risk reduction has so far been mainly focused on the urban setting. This has come as a natural consequence of an increased awareness of the perceived risk of hydro-meteorological extremes in the urban setting where NBS has been one of the measures frequently employed to lower risk to acceptable levels.

Literature shows that people have benefits (e.g. human health and wellbeing) from green and blue spaces. The evidence of assessing this objective indicates that valuation of these benefits in the urban context is dependent on how many people live in near proximity of the area to experience the improved eco-system services that NBS provide. It remains to be described if and how much that will influence decision processes in a setting where population density is lower and where people are further away as is the case in non-urban settings. This calls for development of relevant metrics to measure impacts as well as conscious choices in the NBS design to ensure effects. In a similar manner, nature in a non-urban setting is often of much higher quality than in the urban setting. However, there is still limited evidence of how to link measures to impacts for these metrics. To be able to address nature’s benefits thoroughly and on equal terms to the economic benefits for humans, metrics and decision support systems has to be developed to ensure transparent weighing in cases of opposing benefits and to provide suitable instruments and policies for proper financing.

Financing remains an issue and in many cases, the funding mechanisms and sources has not been presented thoroughly in the analysed repositories of NBS. Many hazard-reducing projects are analysed by means of simple analyses based on financial constraints, or, at best, on socio-economic cost-benefit analyses (CBA). CBA aim to include all benefits and costs created by different project alternatives. It goes beyond a traditional cost analysis, typically limited to investments costs and benefits of reduced flood damages. While CBA is a strong communication tool, it requires that non-market benefits, such as recreation and sense of security, are monetized, in order to account for the many benefits that NBS provide. Valuation techniques for non-market benefits exist, but they are inherently uncertain (Dong et al., 2019). There are examples of CBAs including the benefits of NBS (City of Copenhagen, 2012), but it remains difficult to translate many of the benefits to a traditional monetary scale. It leads to very uncertain assessments and in many examples important benefits are not included in the analysis, leading to systematic underestimation of the benefits of NBS and hence the method tends to favour other solutions. Further, it remains an issue that many of the benefits, even after successful conversion to a monetary scale, are difficult to attribute to individual stakeholders in a tangible way. Therefore, while a socio-economic analysis may clearly indicate a positive outcome for society it remains an issue how to collect these benefits. Traditional means of bankability points towards e.g. collection of fees for using the NBS or increased taxation of local users benefitting from the NBS and can by definition only be applied on PEOPLE indicators, not the overall suite of goals of the NBS. Implementing traditional bankability measures are thus likely to impact the overall socio-economic analysis and hence may jeopardize the business case. The problem of ensuring bankability and a transparent business case may be part of the reason why not a single EU policy specifically addresses the financial aspects of NBS (Davis et al., 2018).

An approach to activate the many benefits of NBS is to consider financing via inclusion of many stakeholders with different interests. They might not have the interest or financial resources to execute the entire NBS solution, but by contributing to different aspects of an NBS project they can ensure that the overall project execution is feasible. Methods for exploring the different stakeholders and finding suitable adaptation pathways for implementing suitable NBS solutions are described in RECONECT Deliverable D1.2.

The overall challenge is to secure that any measure, and in particular measures based on NBS, will provide multiple benefits:

- reduce hydro-meteorological risk, AND
- increase human health and wellbeing, AND
- provide opportunities for habitats and biodiversity, AND
- improve water availability and quality

This should be accomplished without compromising any of the objectives, or, as a minimum, provide better overall performance than traditional measures. Individually, solutions could be optimized for one objective and probably deliver a better result for exactly this purpose; the challenge is to define a set of indicators and decision support system that enables a fair assessment of NBS solutions across all measures and indicators.

Making technical systems such as protection to hydro-climatic extremes is well described in e.g. the Floods Directive, and improving water quality in receiving water bodies has been in focus for almost two decades in Europe through the Water Framework Directive. Making these two objectives go hand in hand is by no means trivial. The complexity increases even further when all the other purposes of water for nature and recreational purposes are added as well as terrestrial ecosystems and with climate changes exacerbating both stressors and limiting predictive power of any measures.

Management of water is becoming increasingly difficult in times of climatic changes and NBS is an important tool in retaining water on a catchment scale. Understanding and utilizing this property is key to designing more holistic solutions that together will be of greater benefit for both nature in itself and people that has to buy in to the solutions. Enabling this opportunity outside of cities is a major task and must be undertaken in cooperation with all relevant stakeholders.

To secure fair and social equitable NBS, a stable policy setting with a long time horizon is needed. The current technological state of NBS is not sufficiently advanced to have reached a stable level and hence policies are needed to promote and facilitate further exploration of NBS. The policy analysis show that there exist policy instruments that promote NBS at global, European and national scales, but also that the policies are fragmented and that NBS is considered “nice-to-have” rather than “need-to-have” in existing policies, even on the urban scale. Still, when considering NBS implemented so far it seems that European policies are more pronounced than local policies, indicating the importance of EU to take a stance on the development of NBS. Developing holistic frameworks and enabling rapid uptake by means of e.g. the Lead User Method are important steps in this regard.

Knowledge about existing projects is key to optimize future implementations of NBS and build on existing knowledge, both positive and negative. The database presented in Chapter 4 is a first step in this direction. It first of all analyse what essential information is needed for an NBS for it to be usable for others to use as experience (see Appendix A) and it draws data from a range of existing platforms to make the present best possible picture of what aggregated data basis for NBS there exist (see Appendix C). There exist amount of knowledge about NBS and we need to systematize and utilize it to make sure that NBS in the future build on the best examples when we manage hydro-climatic extremes for the benefit of nature and people. On a positive note thousands of NBS have been constructed in a wide range of conditions and locations around the globe. Even though many of the registered projects have, to-date, only passively acknowledged the interdisciplinary nature and capacity of their projects to contribute to various benefits of the utilized NBS, they have still been constructed. The potential for NBS should therefore be much larger once the benefits of water-nature-people are explored simultaneously.

Appendix A. Methodology for the Analysis of Databases With a Focus on Supportive Policies

In order to analyse the relevant policy frameworks, a thorough analysis of the existing NBS related repositories/ databases has been performed. The Individual case studies on NBS were collected from existing databases. Based on a technical overview of existing platforms and databases, a total of 12 databases were considered for data collection. Upon further review, the following databases were removed from consideration for reasons stated:

- Climate Scan – inability to filter adaptation projects into any of the NBS concepts
- Disaster Risk Management Center – lack of NBS content
- PANORAMA – information not presented in a consistent manner
- WeAdapt – information not presented in a consistent manner
- Nature-based solutions initiative – underdeveloped content
- Naturvation – too large of a dataset (1000 cases in Europe)
- Thinknature - website states that it is powered by OPPLA (a different database) with the link to the relevant OPPLA web page at the bottom of each case study

This left five databases for data collection, see Table 7.

Table 7 Short description of NBS databases explored for policy frameworks, the number of relevant case studies in each, the content of the individual case studies and data collection process notes specific to each database.

Database	Short Description	Number of Case Studies	Content	Data Collection Process Notes
BISE	The Biodiversity Information System for Europe includes a section on green infrastructure with specific case studies listed by EU member state.	203	• Policy setting • Implementation of GI • Mainstreaming GI • Financing GI • Challenges and opportunities for GI development • Knowledge base	Projects were not detailed in a case by case basis but included within the description for each country. Therefore, each individual project was copied and pasted into a separate Word document before being uploaded to MAXQDA[2]. Only 77% of the cases were included because they had a similar level of detail to what was provided by the other databases. For example, some cases did not list any actions or objectives and simply stated the name of the programme or plan they fell

[2] The software package used to perform the text analysis regarding policies.

				under so these cases were excluded.
Climate-ADAPT	European Climate Adaptation Platform mandated by the EU Adaptation Strategy with section on ecosystem-based adaptation and disaster risk reduction.	47	• Challenges • Objectives • Solutions • Adaptation options implemented • Policy relevance • Stakeholder participation • Success and limiting factors • Costs and benefits • Legal aspects • Implementation time • Lifetime	Any cases in the disaster risk reduction sector with NBS was also categorised under the ecosystem-based adaptation sector on the website. Therefore, any DRR projects that were NBS were automatically included when all cases from the EbA sector were collected. To capture all data on each project, all information on the case study page was copied and pasted into a Word document before being uploaded in MAXQDA.
Natural Hazards – Nature Based Solution	Global NBS platform developed by the World Bank, the Global Facility for Disaster Reduction and Recovery and Deltares with case studies from various European countries.	79	• NBS • Intervention type (green vs. hybrid) • Risk reduction benefits • Additional benefits • Hazard • Scale • Monetary Cost • Monetary benefits • Donors	Pdf files were available for download for each site. All cases were included since the database only contained NBS projects.
OPPLA	EU Repository of NBS with over 60 universities, research institutes agencies and enterprises contributing information.	224	• Objective • Actions taken • Challenges addressed • Potential impacts/benefits • NBS benefits • Transferability of the result • Lessons learned • Financing	The transboundary project between European country and African country (Spain and Morocco) was included since it had one European country involved. International projects were not included. European regional projects were included.
NWRM	The Natural Water Retention Measures (NWRM) website	42	• Policy context • Site characteristics • Design and implementation parameters	The website included both in-depth and light cases. Only in-depth cases were considered due to the extent of information covered. Pdf files of in-

	gathers information on NWRM at the EU level. NWRM are green infrastructure applied to the water sector.		• Biophysical impacts • Socio-economic information • Monitoring and maintenance requirements • Performance metrics and assessment criteria • Main risks, implications, enabling factors and preconditions • Lessons learned	depth case study descriptions were collected for uploading into MAXQDA.

Because NBS is an umbrella concept that encompasses other “green” concepts, it was essential to define all relating terms for determination of applicable projects. The keywords used as search terms to capture all cases related to NBS are listed in Table 8.

Table 8 Neighbouring NBS terms included in data search.

Topic	Keywords
NBS Neighbouring terms (sister concepts)	Nature-based Solution Ecosystem-based solution/management/adaptation/mitigation/approach/framework Ecological engineering Catchment System Engineering Ecological Restoration Green Infrastructure Natural Infrastructure Eco-hydrological solution/management/adaptation/mitigation/engineering Adaptation service Natural Capital River Restoration Natural Capital

Projects were sorted by country in MAXQDA which were then searched for overlapping projects using city or region names, see Table 9 However, documents of repeated projects were not deleted in case the databases provided different information. The information on duplicate projects was combined when exported to excel.

Table 9 Repeated projects and the corresponding databases.

Country	Project	Databases BISE	ClimateADAPT	Natural Hazards - NBS	OPPLA	NWRM
Belgium	Sigma Plan	x	x			
Denmark	Copenhagen Cloudburst Management Plan		x		x	
France	Agroforestry agriculture in Montpellier		x		x	
Germany	Elbe Dike Relocation	x				x
	Emscher Valley Restoration	x	x			
Hungary	Temporary flood water storage in agricultural areas in the Middle Tisza river basin		x	x		
	Climate-adapted management of the Körös-Maros National Park		x			x
Italy	Constructed wetlands as multipurpose green infrastructure in Gorla Maggiore	x			x	
	Greening Rome for human and ecosystem health (Urban-MAES)	x			x	
Luxembourg	Alzette river restoration	x				x
Malta	Aquifer Recharge	x				x
Netherlands	Room for the River Waal		x			x
	Delfland Sand Motor	x	x	X		
	Tidal Park Rotterdam			x	x	
Poland	Urban river restoration a sustainable strategy		x	x		
Portugal	Green corridor Lisbon	x			x	
	More than Cork: Cultural Landscapes in the Montado	x			x	
Slovakia	Adaptation of Bratislava city to Climate Change	x	x		x	
Spain	Implementation of the Vitoria-Gasteiz Green Urban Infrastructure Strategy	x	x		x	
	Barcelona's Green Infrastructure and Biodiversity Plan 2020	x			x	
Sweden	Urban Drainage in Malmo		x	x		
	Multifunctional urban greening in Malmö, Sweden	x			x	
Switzerland	Green roofs in Basel		x		x	

United Kingdom	Climate Proofing Social Housing		x			x
	Hesketh Out Marsh Managed Realignment		x	x		
	Devon Beaver projects			x	x	
	Slowing the Flow at Pickering			x		x
	North Norfolk Coast		x	x		
	London - NBS for a leading sustainable city	x			x	
	Bristol's Parks and Green Spaces Strategy	x			x	
	Belford Natural Flood Management			x		x
Transboundary	Lower Danube floodplain restoration	xxxx	x	x		
	Latvia and Lithuania	xx				

As we were particularly interested in cases that display information on the realisation of NBS project, we focus on cases that included the physical application of NBS and did not consider cases that focused on other aspects of NBS (e.g. exclusive information on financing structures, planning tools, modelling or assessment of implemented NBS, etc.).

Here we focused particularly on information about policies, including relevant European policies (if mentioned), national, regional as well as local policies. Table 10 display the European policies that were included in the analysis (and how they were coded) as well as how we included information on national, regional and local policies. With respect to the Sub-European policies we did not collect more specific information as this was not feasible due to too varied/disperse information provided in the databases.

In addition, we collected information on the following categories in order to analyse with respect to which risks and hazards, challenges and benefits policies are mentioned (see also Table 11 for more detailed information):

- *Risks and Hazards* – climatic risks that were addressed through the NBS measures
- *Challenges* – the challenges addressed per the EKLIPSE framework (Raymond et al., 2017a)
- *Multiple Benefits* – benefits provided by NBS according to the RECONECT framework focused on the main themes of water, nature and people

MAXQDA uses codes to define categories and subcategories. Codes were created for each of the subcategories and a keyword search was conducted to assign relevant codes to the projects (Table 10). To ensure no keywords were missed, a word frequency analysis was conducted using MAXQDA to determine what words were commonly used throughout the documents. Numbers, symbols and any words that were less than three letters were removed from the list. Words that occurred 100 times or more were considered relevant and reviewed for inclusion into the keyword search.

Table 10 Relevant European policies as well as national and regional policies (and search terms).

	Sub-category		Search Terms
Policy	EU	Habitats Directive	“habitat” AND “directive”
			“SAC” OR “SACs” OR “Special Area of Conservation” OR “Special Areas of Conservation”
		Birds Directive	“bird” and “directive”
			“SPA” OR “special protection area” OR “special protection areas”
		Natura 2000	“Natura 2000”
		Floods Directive	“Floods Directive” OR “Flood Directive”
		Water Framework Directive	“Water Framework Directive” OR “WFD”
		EU biodiversity Strategy	“EU” AND “Biodiversity Strategy” OR “Biological Diversity Strategy”
		Life+ and Life	“Life” EXCLUDING “life time” AND “quality of life”
		Common Agricultural Policy	“Common Agricultural Policy” OR “CAP”
		SEA Directive	“SEA” AND “directive”
			“strategic environmental assessment ” OR “strategic environmental assessments”
		EIA Directive	“EIA” OR “environmental impact assessment”
	National		“national” OR “federal” AND “policy” OR “law” OR “regulation” OR “directive” OR “plan” OR “programme” OR “act” OR “strategy”
	Regional		“region” AND “policy” OR “legal” OR “regulation” OR “directive” OR “plan” OR “programme” OR “governance” OR “act” OR “strategy”
	Local		“local” OR “city” OR “municipal” AND “policy” OR “legal” OR “regulation” OR “directive” OR “plan” OR “programme” OR “governance” OR “act” OR “strategy”

Table 11 Relevant sus-categories and search tearms.

	Sub-category	Search Terms
Risks and Hazards	Extreme temperature	“extreme” AND “temperature”
		“heat” AND “wave” OR “stress” OR “island”
	Flooding	“flood” OR “Öood” (MAXQDA recognises some ‘Fl’ as Öood)
	Droughts	“drought”
	Storms	“storm” OR “precipitation” OR “rain” (full words only for rain) OR “rainfall”
	Landslide	“landslide”
	Sea Level Rise	“sea” AND “level” AND “rise” OR “rising” OR “increase” OR “high”
Challenges Addressed	Climate Resilience	“climate” AND “resilience” OR “adapt” OR “mitigate” OR “resilient” OR “mitigation”
		“carbon” OR “CO2” OR “CO^2” AND “sequester” OR “sequestration” OR “storage” OR “store” OR “storing” OR “emission” OR “sink”
		“emission” AND “reduce” OR “low”
	Water Management	“water” OR “flood” OR “Öood” AND “manage” OR “protect” OR “mitigate” OR “reduce” OR “regulate” OR “regulation” OR “retention”
		“hydrological”
	Coastal Resilience	“coast” OR “shoreline” AND “resilience” OR “resilient” OR “protect” OR “manage”
	Green Space Management	“green” AND “space” OR “area” OR “infrastructure” OR “roof” OR “urban” OR “network” OR “corridor”
		“forest” OR “park” OR “garden” OR “tree”
	Air quality	“air” AND “quality” OR “pollution” OR “purification” (use full words for air)
	Urban Regeneration	“urban” OR “city” AND “regeneration” OR “regenerate” OR “restoration” OR “transition” OR “transform” OR “development”
	Participatory Planning and Governance	“participatory” AND “plan” OR “governance”

		“community” AND “collaborative” OR “collaboration” OR “plan” OR “participation” OR “participate”
		“public” AND “participate” OR “participation”
	Social Justice and Cohesion	“social” OR “community” AND “justice” OR “cohesion” OR “inclusion” OR “interact”
	Public Health and Well-being	“health” AND “public” OR “human” OR “improve”
		“well-being” OR “wellbeing” OR “quality of life”
	Economic Opportunities and Green Jobs	“job” OR “economic” OR “economy” OR “income” AND “opportunities” OR “grow” OR “green” OR “increase” OR “create” OR “development” OR “forest” OR “benefit”
		“Cost” And “reduce” OR “reduction” OR “low”
		“employ”
	Disaster Risk Reduction	“risk” OR “hazard” OR “vulnerability” AND “reduction” OR “reduce” OR “mitigate” OR “protect” OR “disaster” OR “manage” OR “mitigation” OR “assess”
Multiple Benefits	Flood Risk Reduction –Rivers and Urban	“river” OR “urban” OR “riparian” AND “flood” OR “Öood” AND “manage” OR “protect” OR “mitigate” OR “reduce” OR “risk” OR “prevent” OR “control” OR “resilience”
		“flow” AND “regulate” OR “regulation” OR “attenuate” OR “attenuation”
		“infiltration” AND “increase” OR “increasing”
		“runoff” AND “reduce”
	Flood Risk Reduction - Coastal	“coast” AND “flood” OR “Öood”
	Groundwater Management	“ground” AND “water” OR “aquifer” AND “manage” OR “maintain” OR “recharge” OR “improve” OR “replenish”
	Drought Risk Reduction	“drought” AND “manage” OR “protect” OR “benefit” OR “mitigate” OR “mitigation” OR “reduce” OR “risk”

	Landslide Risk Reduction	“landslide” AND “manage” OR “protect” “benefit” OR “mitigate” OR “reduce” OR “risk”
		“slope” AND “stabilize” OR “stabilization”
	Surface Water Quality	“water” AND “quality” EXCLUDING “ground” OR “coast”
		“purification”
	Coastal Water Quality	“water” AND “quality” AND “coast”
	Groundwater Quality	“ground” AND “water” AND “quality”
	Habitat Quantity	“habitat” AND “area” OR “create” OR “provide” OR “provision” OR “providing” OR “new” OR “increase” OR “creation” OR “creating”
		“ecological” OR “wildlife” OR “ecosystem” AND “corridor” OR “network” OR “connect”
	Habitat Quality	“habitat” AND “quality” OR “improve” OR “improving” OR “restore” OR “restoration” OR “restoring” OR “distribute” OR “enhance” OR “enhancing” OR “diverse” OR “diversity” OR “gene” OR “protect” OR “conserve” OR “maintain” OR “maintenance”
	Ecological Status and Physical Structure of Habitats	“status” AND “ecological” OR “ecosystem”
	Land Use Type	“land” AND “use” AND “change” OR “transform” OR “transition”
	Biodiversity	“biodiversity” OR “biological” AND “diversity” AND “improve” OR “increase” OR “higher” OR “enhance” OR “benefit” OR “support” OR “protect” OR “impact” OR “provide” OR “preserve” OR “conserve” OR “revitalise” OR “great” OR “improving” OR “conserving”
	Reduce Disturbance to Ecosystems	“ecosystem” OR “wetland” OR “river” OR “environment” OR “nature” OR “forest” AND “protect” OR “preserve” OR “preservation” OR “conserve” OR “conservation” OR “restore” OR “restoration”
	Recreational Opportunities	“recreation” OR “tourism” OR “enjoy” OR “leisure”
	Education and Awareness	“education”

		"awareness" AND "raise" OR "raising" OR "increase"
		"information" AND "communicate" OR "disseminate"
	Cultural Values	"cultural" (find whole words) AND "value" OR "opportunities" OR "benefit" OR "heritage" OR "diversity"
	Accessibility	"accessibility" OR "accessible"
	Community Cohesion	Coded the same as Challenges Addressed: Social justice and cohesion
	New Business Models	"business" OR "production" AND "model"
	Economic Benefits	Coded the same as Challenges Addressed: Potential for economic opportunities and green jobs
	Health and wellbeing impacts (combined direct and indirect since it would be challenging to distinguish the two in the analysis)	Coded the same as Challenges Addressed: Public health and well-being

Appendix B. Requirement Analysis for NBS Database

B.1 *Objectives*

Exploring the use of NBS for hydro-meteorological risk reduction is essential to ensure the capability for future socio-economic development (Faivre et al., 2018). In this respect, the European Commission has been investing considerably in the research and innovation of NBS or Ecosystem-based Adaptation (EbA), and some recent efforts have been placed on practical demonstration of NBS for climate change adaptation and risk prevention (Faivre et al., 2017).

The European Commission promotes innovative 'science-policy-society' mechanisms, including the use of knowledge-exchange platforms, to engage society in NBS' co-creation processes.

The objective for the construction of a geodatabase is to store, in a structured manner, current knowledge in relation to existing NBS projects contained in several online platforms and visualize this information spatially. This facility is important for RECONECT for at least two reasons. One is the ability to rapidly perform gap analysis in the current knowledge base and the other is to structure and prepare information (i.e., the knowledge and experiences that will be generated throughout the life of the project) in a form that can serve project's dissemination and knowledge sharing activities.

B.2 *Definition of Functional and Spatial Requirements*

The database functional requirements were defined based on the objectives stated in the RECONECT project. The implemented database contains data to graphically represent, in the form of a map, whether or not a specific country has information reported on NBS projects and if so, the characteristics of the NBS projects in the related platforms.

B.3 *Definition of Data Requirements*

Table 12 lists those attributes, together with their description, that have been identified as relevant to provide insight knowledge on the state-of-the-art of NBS projects per country reported in the selected platforms.

Table 12 Data requirements identified to provide insight on NBS projects reported in the selected platforms.

ATTRIBUTE	DESCRIPTION	ATTRIBUTE	DESCRIPTION
CODE	Corresponds to an abbreviation name of each web platform. This code is used in the relational join with the geographical component	River	Contains a domain whether or not the platform contains information regarding NBS on river scale
Name	Full Name of the platform	Urban	Contains a domain whether or not the platform contains information regarding NBS on urban scale
References/Website	web link to access each platform	Coastal	Contains a domain whether or not the platform contains information regarding NBS on coastal scale
Terminology used	It contains the main words used to describe the **Nature** based solutions	Mountainous	Contains a domain whether or not the platform contains information regarding NBS of mountainous scale
Scale level	Contains the scale of reporting of the NBS platform. i.e. global, Europe, etc.	Discuss policy	Contains a domain whether or not the platform contains information of policy discussion
How many projects in total	How many NBS projects are reported in the platform	Science (Publication)	Contains a domain whether or not the platform contains information regarding scientific publications of the NBS projects
How many countries in total	In how many countries there are NBS projects are reported in the platform	NBS	Contains a brief description of the type of NBS solutions implemented where available
How many projects in each country?	A list with each country with NBS reported and the associated number of projects	Hybrid	Contains a domain whether or not the platform contains information of hybrid
Funded by	Who finance the platform	Lesson learned	Contains a domain whether or not the platform contains information regarding the lessons learnt on the NBS
Purposes	What are the objectives/Purpose of the platform	Cost	Contains a domain whether or not the platform contains information regarding the cost on the NBS
Contents	What type of information can be consulted in the	Funders	Contains a domain whether or not the platform contains

	platform for each NBS project		information regarding who funded the NBS
Benefits	What are the main advantages and/or characteristics of each platform	Design criteria	Contains a domain whether or not the platform contains information regarding the different design criteria of the NBS
Gaps	It contains the drawbacks or what can be improved in each platform	Main benefit	Description of what are the main benefits achieved with the implementations of the different NBS projects reported in the platforms
Visualisation	It contains a image / screenshot of how the platform looks like	Co-benefits	Contains a domain whether or not the platform contains information regarding co-benefits as a result of the NBS implementation
Project information (Objective)	Contains a domain whether or not the platform contains information regarding the objectives of the project	Others	Description of other benefits achieved by the implementation of the NBS
Project information (Area characteristics)	Contains a domain whether or not the platform contains information regarding the area characteristics of the project	Global scale	Contains a domain whether or not the platform contains information regarding NBS implemented on a global scale
Project information (Challenges)	Contains a domain whether or not the platform contains information regarding the challenges faced on each project reported	Continental scale	Contains a domain whether or not the platform contains information regarding NBS implemented on a continental scale
Project information (Solutions)	Contains a domain whether or not the platform contains information regarding the solutions adopted on each project reported	National	Contains a domain whether or not the platform contains information regarding NBS implemented on a national scale
Large NBS	Contains a domain whether or not the platform contains information regarding NBS of large-scale	Local	Contains a domain whether or not the platform contains information regarding NBS implemented on a local scale
Small NBS	Contains a domain whether or not the platform contains	International	Contains a domain whether or not the platform contains information regarding NBS

	information regarding NBS of small scale		implemented on an international scale
		Regional	Contains a domain whether or not the platform contains information regarding NBS implemented on a regional scale

Appendix C. Design and Implementation of NBS Database

C.1 Database Design

Entity-Relationship Diagram (ERD)

The ERD was used to represent the entities, their attributes, and the relationships between those entities (Figure 26). Two entity types are identified, “Country” to represent countries of the world and “Platform” to represent the selected platforms. The relationship between these two entity types is a many-to-many relationship given that a country is associated with none or several instances of a platform, and vice versa. This relationship has an attribute “num_projects” to represent the number of projects in each of the platforms associated with a country. The attributes of “Country” include the identifier of the country and the country name (primary identifying attribute), whereas the attributes of “Platform” were those described in the data requirements section above (with the coded name of the platform as the primary identifying attribute).

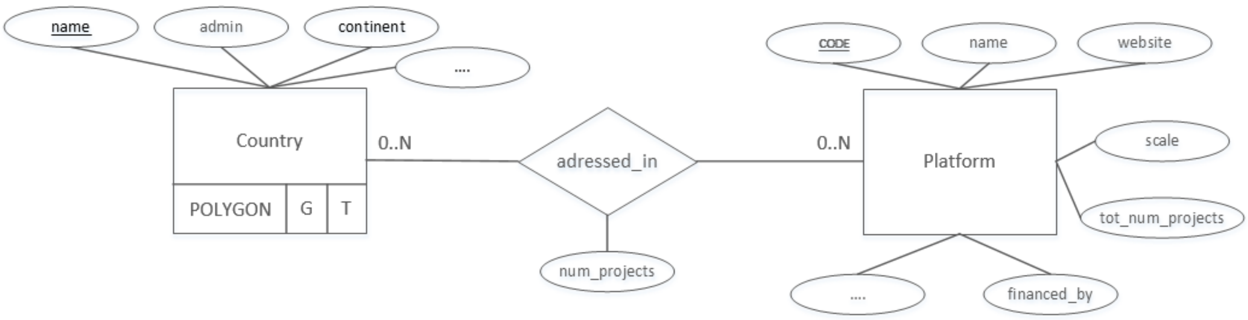


Figure 26 Entity-Relationship Diagram.

Data Dictionary

The data dictionary created for the geodatabase (Data_dictionary_database_RECONECT.xlsx) contains all the specifications for the two entities in the geodatabase, i.e., the spatial entity “Country” representing world countries and the relational table “Platform” containing the relevant information for each selected platform. For the latter table, attribute characteristics were defined such as the data type, whether the attribute can/not be Null, whether the attribute values are unique, whether the attribute is associated to a domain (collection of possible values), if the attribute is the primary key of the relation, and a short description of each attribute (the data dictionary is included in Appendix D).

Logical/Geodatabase Model

The logical model for this geodatabase is presented in Figure 27.

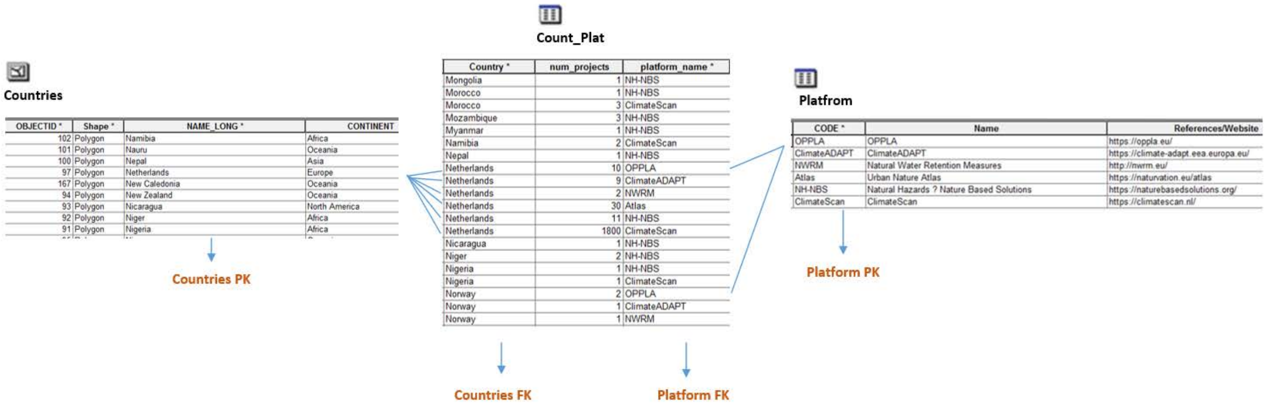


Figure 27 Logical geodatabase model.

The entity “Country” in the ERD became the “Countries” shapefile (with its associate table) and the entity “Platform” became table “Platform”. Attributes in the ERD became columns in the corresponding tables and each primary identifying attribute became a primary key. The many-to-many relationship between “Country” and “Platform” was translated into table “Count_Plat” which had as foreign key attributes those associated with the primary key values from the two tables.

C.2 Geodatabase Implementation

The implementation of the geodatabase and the way to use is provided below.

Geodatabase Creation

The geodatabase was based on the data and functional requirements of the RECONECT project. The implementation consisted on the creation of the “Countries” shapefile (countries of the world administrative divisions) and two relational tables. Table “Platform” contained relevant information extracted for each selected platform, and the intermediate relationship table “Count_Plat” was created to map the associations between countries and platforms. Using the latter table, the relationship class “Countries_Platform” with many-to-many cardinality was created.

Data Upload

A shapefile of the world was used as a base to construct and fill in the information. The basic information contained in the shapefile are the country names and administrative characteristics. The data regarding which country has reported NBS projects for each platform was obtained by using the join functionalities of the software with a pre-filled excel table, prepared by the Reconect team, containing the relevant information per platform (as shown in Table 12). The information contained in table “Count_Plat” was prepared from the data in the Excel file and it contains one record per each country that is listed in each of the different NBS platforms. Also, attribute “num_projects” shows the number of NBS projects in the country contained in the selected platform (Figure 28). Table “Platform” contains all the information collected from the different NBS platforms (Figure 29)

OBJECTID *	Country *	platform_name *	num_projects
1	Afghanistan	NH-NBS	1
2	Australia	ClimateScan	513
3	Austria	ClimateADAPT	5
4	Austria	NWRM	4
5	Austria	ClimateScan	1
6	Azerbaijan	ClimateScan	1
7	Bangladesh	NH-NBS	6
8	Barbados	NH-NBS	1
9	Belgium	OPPLA	17
10	Belgium	ClimateADAPT	6
11	Belgium	NWRM	4
12	Belgium	Atlas	20
13	Belgium	ClimateScan	47
14	Belize	NH-NBS	2
15	Benin	NH-NBS	1
16	Brazil	NH-NBS	2
17	Brazil	ClimateScan	9
18	Bulgaria	ClimateADAPT	3
19	Bulgaria	NWRM	12
20	Bulgaria	Atlas	20
21	Burkina Faso	NH-NBS	1
22	Burkina Faso	ClimateScan	1
23	Canada	ClimateScan	25

Figure 28 Screenshot of the "Count_Plat" table in the geodatabase.

CODE *	Name	References_Website	Terminology_used	Scale_le
OPPLA	OPPLA	https://oppla.eu/	Nature-Based Solution, Natural capital, Ecosystem services	Global
ClimateADAPT	ClimateADAPT	https://climate-adapt.eea.europa.eu/	EbA, Nature-Based Solution, GI	Europe
NWRM	Natural Water Retention Measures	http://nwrm.eu/	Natural water retention measures	Europe
Atlas	Urban Nature Atlas	https://naturvation.eu/atlas	Nature-Based Solution	Europe
NH-NBS	Natural Hazards ? Nature Based Solutions	https://naturebasedsolutions.org/	Nature-Based Solution	Global
ClimateScan	ClimateScan	https://climatescan.nl/	Blue-Green Infrastructures	Global

Figure 29 Screenshot of the "Platform" table in the geodatabase.

Once the data was uploaded into the database, the relationship class "Countries_Platform" was created using the "Table to Relationship Class" in the "Data Management" toolbox. Table "Count_Plat" was used as the relationship table, "Countries" as the origin table, "Platform" as the destination table (information to be returned when identifying a country), and "many-to-many" as the cardinality of the relationship (Figure 30).

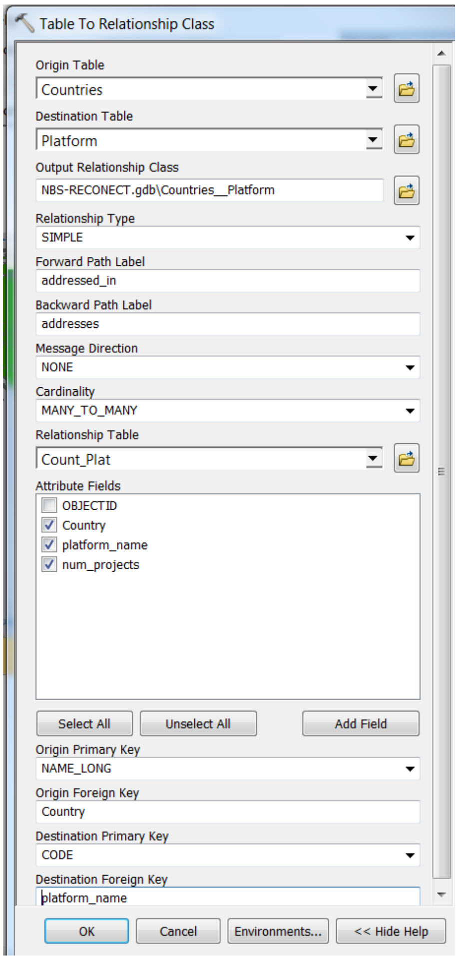


Figure 30 Creation of the “Countries_Platform” relationship class.

Appendix D. Data Dictionary for Relational Table "Platform" in NBS Database

ATTRIBUTE	TYPE	Null	UNIQUE	DOMAIN	Primary Key	DESCRIPTION
CODE	Text (15)	NO	YES	NO	YES	Corresponds to an abbreviation name of each web platform. This code is used in the relational join with the geographical component
Name	Text (15)	NO	YES	NO	NO	Full Name of the platform
References/Website	Text (unlimited)	NO	NO	NO	NO	web link to access each platform
Terminology used	Text (unlimited)	YES	NO	NO	NO	It contains the main words used to describe the Nature based solutions
Scale level	Text (15)	YES	NO	NO	NO	Contains the scale of reporting of the NBS platform. i.e. global, Europe, etc.
How many projects in total	Integer	NO	NO	NO	NO	How many NBS projects are reported in the platform
How many countries in total	Integer	NO	NO	NO	NO	In how many countries there are NBS projects are reported in the platform
How many projects in each country?	Text (unlimited)	NO	NO	NO	NO	A list with each country with NBS reported and the associated number of projects
Funded by	Text (15)	YES	NO	NO	NO	Who finance the platform
Purposes	Text (unlimited)	YES	NO	NO	NO	What are the objectives/Purpose of the platform
Contents	Text (unlimited)	YES	NO	NO	NO	What type of information can be consulted in the

						platform for each NBS project
Benefits	Text (unlimited)	YES	NO	NO	NO	What are the main advantages and/or characteristics of each platform
Gaps	Text (unlimited)	YES	NO	NO	NO	It contains the drawbacks or what can be improved in each platform
Visualisation	Raster	YES	NO	NO	NO	It contains a image / screenshot of how the platform looks like
Project information (Objective)	Text (15)	YES	NO	YES : Y or N	NO	Contains a domain whether or not the platform contains information regarding the objectives of the project
Project information (Area characteristica)	Text (15)	YES	NO	YES : Y or N	NO	Contains a domain whether or not the platform contains information regarding the area characteristics of the project
Project information (Challenges)	Text (15)	YES	NO	YES : Y or N	NO	Contains a domain whether or not the platform contains information regarding the challenges faced on each project reported
Project information (Solutions)	Text (15)	YES	NO	YES : Y or N	NO	Contains a domain whether or not the platform contains information regarding the solutions adopted on each project reported
Large NBS	Text (15)	YES	NO	YES : Y or N	NO	Contains a domain whether or not the platform contains information regarding NBS of large-scale

Small NBS	Text (15)	YES	NO	YES : Y or N	NO	Contains a domain whether or not the platform contains information regarding NBS of small scale
River	Text (15)	YES	NO	YES : Y or N	NO	Contains a domain whether or not the platform contains information regarding NBS on river scale
Urban	Text (15)	YES	NO	YES : Y or N	NO	Contains a domain whether or not the platform contains information regarding NBS on urban scale
Coastal	Text (15)	YES	NO	YES : Y or N	NO	Contains a domain whether or not the platform contains information regarding NBS on coastal scale
Mountainous	Text (15)	YES	NO	YES : Y or N	NO	Contains a domain whether or not the platform contains information regarding NBS of mountainous scale
Discuss policy	Text (15)	YES	NO	YES : Y or N	NO	Contains a domain whether or not the platform contains information of policy discussion
Science (Publication)	Text (15)	YES	NO	YES : Y or N	NO	Contains a domain whether or not the platform contains information regarding scientific publications of the NBS projects
NBS	Text (unlimited)	YES	NO	NO	NO	Contains a brief description of the type of NBS solutions implemented where available
Hybrid	Text (15)	YES	NO	YES : Y or N	NO	Contains a domain whether or not the platform contains

						information of hydbrid
Lesson learned	Text (15)	YES	NO	YES : Y or N	NO	Contains a domain whether or not the platform contains information regarding the lessons learnt on the NBS
Cost	Text (15)	YES	NO	YES : Y or N	NO	Contains a domain whether or not the platform contains information regarding the cost on the NBS
Funders	Text (15)	YES	NO	YES : Y or N	NO	Contains a domain whether or not the platform contains information regarding who funded the NBS
Design criteria	Text (15)	YES	NO	YES : Y or N	NO	Contains a domain whether or not the platform contains information regarding the different design criteria of the NBS
Main benefit	Text (unlimited)	YES	NO	NO	NO	Description of what are the main benefits achieved with the implementations of the different NBS projects reported in the platforms
Co-benefits	Text (15)	YES	NO	YES : Y or N	NO	Contains a domain whether or not the platform contains information regarding co-benefits as a result of the NBS implementation
Others	Text (unlimited)	YES	NO	NO	NO	Description of other benefits achieved by the implementation of the NBS
Global scale	Text (15)	YES	NO	NO	NO	Contains a domain whether or not the

						platform contains information regarding NBS implemented on a global scale
Continental scale	Text (15)	YES	NO	NO	NO	Contains a domain whether or not the platform contains information regarding NBS implemented on a continental scale
National	Text (15)	YES	NO	NO	NO	Contains a domain whether or not the platform contains information regarding NBS implemented on a national scale
Local	Text (15)	YES	NO	NO	NO	Contains a domain whether or not the platform contains information regarding NBS implemented on a local scale
International	Text (15)	YES	NO	NO	NO	Contains a domain whether or not the platform contains information regarding NBS implemented on an international scale
Regional	Text (15)	YES	NO	NO	NO	Contains a domain whether or not the platform contains information regarding NBS implemented on a regional scale

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