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Assessment frameworks of nature-based solutions for climate change adaptation and disaster risk reduction

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Abbreviations

BGI - Blue and Green Infrastructure
CCA - Climate Change Adaptation
CBD - Convention on Biological Diversity
DG - Directorate-General
DRR - Disaster Risk Reduction
DRM - Disaster Risk Management
EA - Ecosystem Approach
EbAp - Ecosystem-based Approaches
EbA - Ecosystem-based Adaptation
EbM - Ecosystem-based Management
EC - European Commission
Eco-DRR - Ecosystem-based Disaster Risk Reduction
EEA- European Environmental Agency
ETC/CCA - European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation
EU - European Union
GI - Green Infrastructure
IUCN - International Union for Conservation of Nature
NBS - Nature-based Solutions
NCS - Natural Climate Solutions
NDC - Nationally Determined Contribution
NWRM - Natural Water Retention Measure
SCA - Sustainable Climate Actions
SFDRR - Sendai Framework for Disaster Risk Reduction
SFM - Sustainable Forest Management
SM - Sustainable Management
UN - United Nations
UNFCCC - United Nations Framework Convention on Climate Change

Abstract

Nature-based solutions (NBS) play an important and increasing role in both adaptation and disaster risk management. This is also recognized within several global and European agreements and policies (e.g., UN's SFDRR, EU Green Deal, the EU Adaptation Strategy) which embed NBS as a means to address climate change adaptation (CCA) and disaster risk reduction (DRR) as well as other societal challenges (e.g., biodiversity loss, climate mitigation). This calls for fit-for-purpose assessments, which critically assess the suitability of NBS for addressing climate change and other hazard impacts and monitor the success of their implementation, to inform (future) policies and actions, as well as evaluate implemented policies.

The technical paper provides a concise overview of available NBS assessment approaches in the context of adaptation to climate change and disaster risk reduction, based on information from literature and selected European cases. The first theoretical part looks at the reasoning behind and purpose of carrying out NBS assessments and the available methodological approaches matching decision-makers' needs. Here, we present a step-wise framework for designing user-oriented NBS assessments, building on key success factors and limitations identified in the literature. The second part looks at real-world lessons learned from successes and challenges in working with NBS assessments and illustrate a range of different NBS assessment approaches applied in Europe for a wide range of NBS assessment purposes and uses. The report concludes with a reflection on key elements for designing and implementing NBS assessments drawn from the insights gained in this study.

1 Introduction

1.1 Context

In 2019, the EEA (supported by the ETC/CCA) produced a scoping paper on nature-based solutions (NBS) for climate change adaptation (CCA) and disaster risk reduction (DRR) applied in Europe, which formed the basis for the development of the EEA report N° 1/2021 "Nature-based solutions in Europe: Policy, knowledge and practice for climate change adaptation and disaster risk reduction" (EEA, 2021). The EEA report:

- Introduces the NBS concept as an umbrella term covering a range of established nature-based approaches which aim to increase resilience to climate change; and providing an overview of current definitions and applications of NBS for CCA and DRR;
- Explores how NBS are mainstreamed across the relevant policy frameworks at international and EU levels that drive climate change adaptation and disaster risk reduction;
- Presents the main elements of the increased knowledge base about NBS (in different sectors and thematic areas: water, forests and forestry, agriculture, urban and coastal areas) and highlights the main opportunities and limitations for NBS implementation;
- Describes solutions and practical measures in selected European NBS practical cases (case studies) in different sectors and thematic areas; and
- Provides an overview of relevant financing instruments for NBS for CCA and DRR in Europe.

The EEA report stresses the importance of assessment methods including evaluation frameworks and monitoring mechanisms to assess NBS performance (e.g., quantifying multiple benefits and trade-offs of NBS) and to improve mainstreaming into regulations, norms and plans, for example, by the use of agreed standards, targets and indicators. Although a systematic review of assessment methods was not among its specific objectives, the EEA report highlights the lack of structured information on this topic. For example, only about 15% of the NBS case studies analysed appear to employ monitoring and/or evaluation and this is often limited to the duration of the NBS project or initiative. The generation and dissemination of monitoring and evaluation data on NBS performances are, however, vital to better inform the development of policies aiming to mainstream NBS in land management and urban development. The paucity of detailed and standardised assessment methods, reporting protocols and (technical) guidance describes a major challenge for up-scaling and replication of NBS, which was also emphasised by the recently published H2020 publication 'Evaluating the impact of nature-based solutions: A handbook for practitioners' (EC, 2021a) and by other international literautre on NBS for CCA and DRR (Donatti, et al., 2021; Vouk, Pilechi, Provan, & Enda, 2021).

1.2 Objectives, scope and key target groups

The objective of this report is to provide a concise overview of available NBS assessment frameworks in the context of adaptation to climate change and disaster risk reduction, based on the information from literature and selected European cases. It looks at the potential and realised application of assessment frameworks for NBS in both ex-ante and ex-post phases as well as during implementation, generating output metrics in support of policy and decision-making as well as of practitioners' work. The report may also be used as guidance for the selection of an appropriate assessment approach for the various purposes within NBS projects.

The target audience of this technical paper is composed of policy-makers, decision-makers and practitioners at the European, national and subnational levels who work with NBS in the context of CCA and DRR. The paper provides information on available assessment frameworks for NBS, linking to the entry points in CCA and DRM cycle (disaster risk management cycle), and highlights key considerations around method choice and application. It does not aim to be a comprehensive or detailed guide for carrying out

NBS assessments. Instead, it links to additional material available for further exploration and technical methodological guidance, such as (EC, 2021a), (Donatti, et al., 2021), the research and demonstration investments into NBS interventions within Horizon 2020 and Horizon Europe-funded research projects (EC, 2020b) and the EC information website on NBS (EC, n.d.), which provide relevant insights and serve as key references for our more concise analysis.

1.3 Structure and methodology

The report consists of two main parts. The first theoretical part looks at the reasoning behind and purpose of carrying out NBS assessments and the available methodological approaches matching decision-makers' needs. The second part looks at real-world lessons learned concerning successes and challenges in working with NBS assessment and illustrate a range of different NBS assessment approaches applied in Europe.

More specifically, the report is formed by four chapters. First, **Chapter 1** provides a common background on NBS assessment terminologies used in the report (Section 1.4) and policy links (Section 1.5), based on the outcome of the recently published EEA report N° 1/2021 (EEA, 2021). This chapter is followed by **Chapter 2**, which aims to devise an overarching framework for strategic planning of NBS assessment in the context of CCA and DRR. To that end, this chapter discusses key success factors and limitations of NBS assessments identified in existing literature (Section 2.1) and develops a step-wise framework for designing a NBS assessment (Section 2.2), accounting for the specific purposes for which NBS assessments can be undertaken in the CCA and DRR contexts, the additional synergistic purposes these assessments may serve as well as the key methodological characteristics that guide the assessment design and the final choice of the best suited approach. **Chapter 3** focuses on the analysis of existing real-life NBS assessments implemented across the European Union (EU)[1]. These NBS case studies provide insights into the extent to which the identified assessment approaches (Chapter 2) have been applied and the context in which the assessments are chosen, designed and implemented, and what role assessment have played in decision-making. The case study analysis builds upon previous work done for the EEA report N° 1/2021 (EEA, 2021) but case studies are explored from a different angle for this report focusing on the practice and experience involved in applying assessments at different stages of the NBS project cycle. A selection of case studies where specific assessment frameworks or actions have been implemented are discussed in more detail (Section 3.3). The paper concludes in **Chapter 4** with a reflection on key elements for designing and implementing NBS assessments drawn from the insights gained in this study.

An informal advisory group of representatives of different DGs of the European Commission and experts in various NBS related fields was set up to support, since the formulation of the extended outline, and review the development of this report.

[1] We note, that NBS projects from outside the EU (e.g., Global South) may help to further inform the uptake of NBS for CCA and DRR initiatives in Europe, however, due to the scope of this study, we did not include in-depth analysis of international case studies, but have taken account for lessons learnt from international literature in the development of the theoretical backbone of this study.

1.4 Terms and definitions

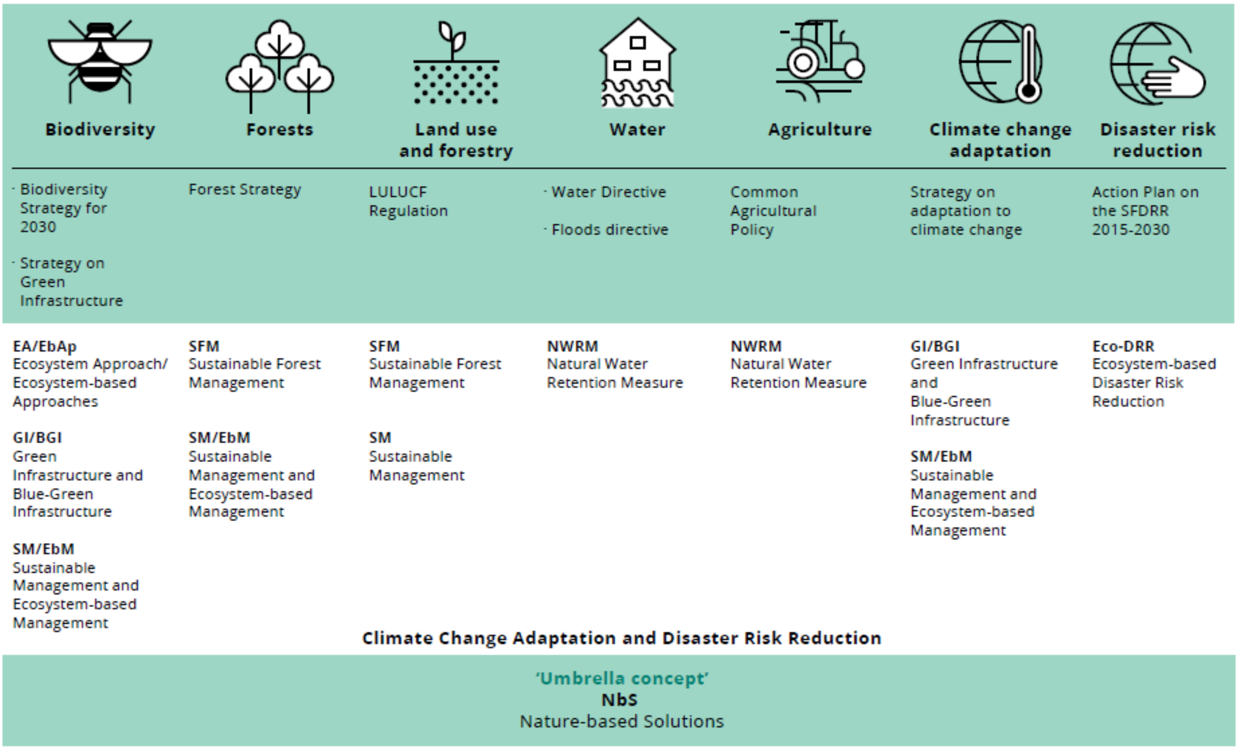
1.4.1 NBS as an umbrella concept

The scientific literature and prevailing policy discourse largely frame NBS as an 'umbrella concept' for all established ecosystem-based approaches aiming to address societal challenges by working with nature (e.g., ecosystem-based approaches, sustainable forest management, green infrastructure) (IUCN, 2016; Nesshöver, et al., 2017). Commonly used definitions are provided by the International Union for Conservation of Nature (IUCN) and European Commission (EC). The IUCN defines NBS as "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously provide human well-being and biodiversity benefits" (IUCN, 2016). The EC recognizes NBS as solutions to societal challenges that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience by bringing more and diverse, nature and natural features and processes into cities, landscape and seascapes (EC, n.d.; EC, 2015).

The NBS concept is based on a scientific understanding of functioning ecosystems and their services to human society (i.e., supporting, regulating, provisioning and cultural). NBS must therefore benefit biodiversity and support the delivery of a range of ecosystem services (EC, n.d.). The principles and safeguards included in the 'Voluntary guidelines for the design and effective implementation of ecosystem-based approaches to climate change adaptation and disaster risk reduction' (CBD, 2019) apply also for NBS. These approaches aim to manage land, water, sea and living resources in a way that promotes conservation and sustainable use in a holistic and equitable way. Thus, management that harness ecological processes and do not support biodiversity, such as planting non-native monoculture, genetic engineering or intensive farming, are more vulnerable to environmental change in the long term and are not considered an ecosystem-based approach, and thus do not qualify as sound/effective NBS ((Seddon, et al., 2020a); (UNDRR, 2021)).

This report focuses on the NBS and related approaches in the context of climate change adaptation and disaster risk reduction, hence aiming to increase resilience to climate change. The approaches relating to NBS for CCA and DRR have developed from a variety of backgrounds and can be categorised as follows:

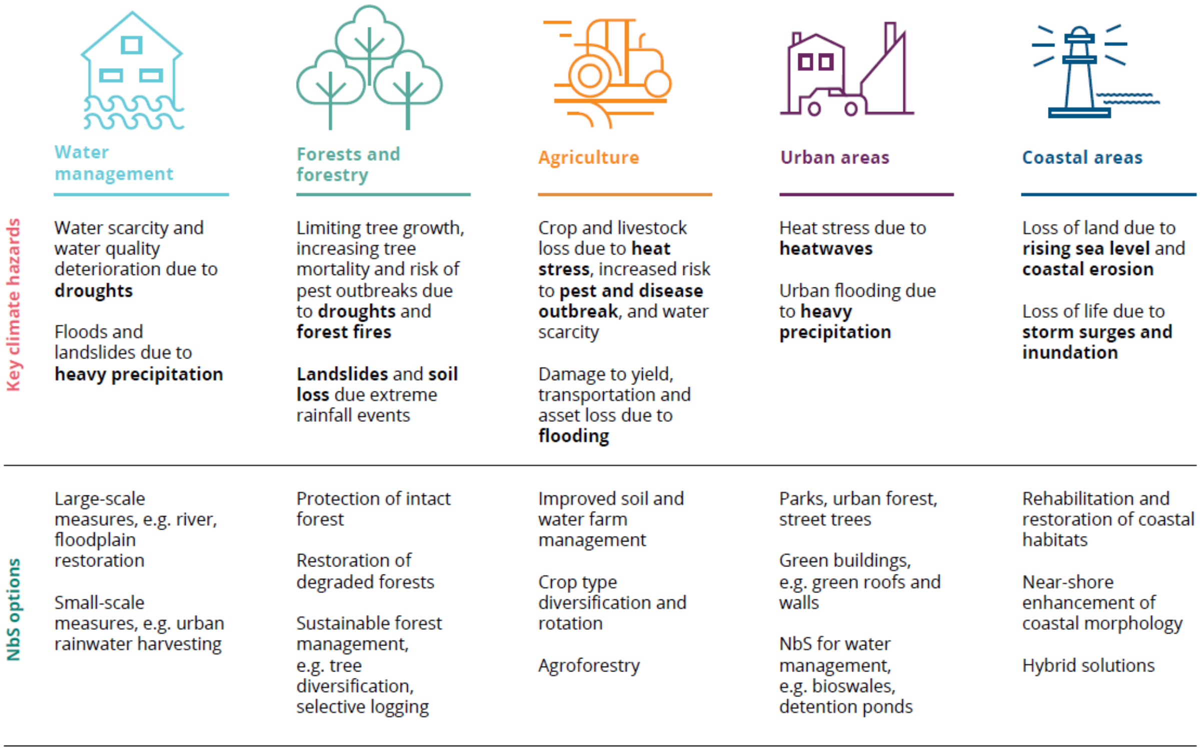
- Ecosystem approach (EA) and ecosystem-based approaches (EbAp);
- Ecosystem protection and restoration approaches: sustainable forest management (SFM), sustainable management (SM), ecosystem-based management (EbM);
- Infrastructure-related approaches: green infrastructure (GI), blue-green infrastructure (BGI);
- Issue-specific ecosystem-related approaches:
  - Climate change adaptation: ecosystem-based adaptation (EbA);
  - Flooding: natural water retention measures (NWRM);
  - Disaster risk reduction: ecosystem-based disaster risk reduction (Eco-DRR);
  - Climate mitigation: sustainable climate actions (SCA), natural climate solutions (NCS) (Figure 1, for a detailed analysis see EEA (2021)).



Note: CAP, common agricultural policy; LULUCF, Land use, land use change and forestry; SFDRR 2015-2030, Sendai Framework for Disaster Risk Reduction 2015-2030.

Source: EEA.

NBS encompasses a wide range of interventions including conservation and restoration of ecosystems (e.g., floodplain restoration, protection of intact forests), sustainable management and climate-proofing of ecosystems (e.g., agroforestry, sustainable forest management), and creation of new, engineered ecosystems for reducing the impact of climate change (e.g., green buildings, green dykes, vegetated levees) (Figure 2) (Eggermont, et al., 2015; EEA, 2021).



1.4.2 Key elements and terms of 'NBS assessments' used in this report

NBS assessments are essential to operationalize the concept. They enable to measure the 'success' of an individual NBS project (e.g., how does the NBS project perform or how effective is the NBS in addressing climate change or other hazard impacts) and to optimise future management and policy making (EC, 2021a). The report uses the following terms in this context:

- An **assessment** refers to a wide variety of approaches, methods or tools that can be used for a critical evaluation of information, to inform decisions on complex, public issues. In case of assessments that link science and policy, "assessment is defined as a process through which scientist, decision-makers and advocates interact to define relevant questions or issues, mobilize experts and expertise and provide options for decision-makers to consider" (MEA, 2005).
- "**Evaluation** is a periodic, objective assessment of a planned, ongoing or completed NBS project and answers specific questions related to design, implementation and results" (EC, 2021a).
- **Monitoring** is the "process of systematically collecting and analysing data and information in order to detect signs of change in relation to baseline" (GIZ, UNEP-WCMC and FEBA, 2020). With regard to NBS, monitoring can be described by the continuous process that can track the implementation, measure the NBS performance against expected results and/or compared with measurements of a reference situation or/and towards certain target (EC, 2021a).
- **"Assessment approaches"** in this report is used to denote different (combinations of) methods to evaluate, value or monitor NBS.

There are different **entry points** for an NbS assessment within CCA and disaster risk management[2] (DRM) planning cycles (see Figure 5 and Figure 6 in Section 2.2.1), which relate to and guide the **purpose** of the NbS assessment – the decision, process or policy it aims to inform (Section 2.2.1). In relation to NbS planning and implementation process, the assessments may be categorised as **ex-ante** (i.e., before NbS is implemented; decision support assessments for the selection and design of NbS and assessment of potential impact), **operational phase** (i.e., during NbS implementation/operation) and **ex-post** (i.e., after NbS has been implemented; evaluation and monitoring of NbS) assessments; and being technical/physical, economic or environmental/social impact oriented (see Section 2.2.1.3).

Several NBS assessment frameworks have been suggested (see, e.g., Calliari et al. (2019) and EC (2021a). Collaborative, co-productive approaches including knowledge, expertise and lived experiences of many stakeholders have been highlighted as being particularly relevant for robust NBS impact assessments (EC, 2021a). These commonly include three key elements: (i) **multi-functionality** (simultaneous delivery of economic, environmental and social benefits), (ii) **cost-effectiveness**, and (iii) **co-production** of scientifically sound knowledge through multi-stakeholder engagement (Raymond, et al., 2017; Calliari, Staccione, & Mysiak, 2019; EC, 2021a).

1.5 Links to global and EU policies

A wide set of global and European policies was analysed in the previous EEA report (EEA, 2021) to examine whether and to what degree NBS are explicitly or implicitly supported as tools for CCA and DRR. Table 1 summarizes key policy frameworks which are considered as having strong explicit support for NBS (i.e., explicit mention of NBS in connection with CCA and/or DRR; and strong embedding throughout the policy, including in objectives, actions and instruments).

Global policy agreements recognize the role nature plays in promoting sustainable development and building resilience against disaster and climate change (EEA, 2021). For example, the Sendai Framework for Disaster Risk Reduction - SFDRR (UNDRR, 2015) recognizes the role of ecosystems and environment as cross-cutting issues in DRR, emphasising that ecosystems need to be considered in undertaking risk assessments, in risk governance and in investing in resilience. Furthermore, the Paris Agreement (UNFCCC, 2015) recognized the need to protect the integrity of ecosystems and biodiversity for climate change adaptation and mitigation. Many of the nationally determined contributions (NDCs) submitted to the United Nations Framework Convention on Climate Change (UNFCCC) in 2019 included NBS in their adaptation and mitigation plans (Seddon, et al., 2020b). Convention on Biological Diversity (CBD) policy documents offer strong explicit support for NBS, e.g., the zero draft of the post-2020 global biodiversity framework includes among the 2030 targets a specific one related to NBS and EbAp for addressing climate impacts (CBD, 2020).

Within the European policy arena, NBS are especially highlighted in the recently released European Green Deal (placing NBS as the centre of the work on climate adaptation and mitigation) and its associated policy initiatives, such as the EU Biodiversity Strategy for 2030 (EC, 2020a) and the EU Strategy on Adaptation to Climate change (EC, 2021c). The former refers to NBS as an essential tool for emission reduction and climate adaptation and ecosystem restoration, while the latter aims to make the EU climate-resilient by 2050 and explicitly recognizes the role of NBS for increasing climate resilience and contributing to multiple European Green Deal objectives. Here, it is highlighted that Europe needs to leverage more investments in nature-based solutions to generate gains for adaptation, mitigation, disaster risk reduction, biodiversity, and health.

[2] DRM is the organisation, planning and application of measures preparing for, responding to and recovering from disaster (UNDRR, 2017). DRM and DRR are interlinked: DRR is the policy objective of DRM, and the goals and objectives of the latter are defined in the DRR strategies and plans (EEA, 2021).

Table 1: Key international and EU policies with a strong explicit reference to NBS (and related terms) for addressing CCA and DRR (adapted from EEA, (2021).

Policy area	Policy	International / EU	NBS-related term	Reference to DRR	Reference to CCA
Disaster Risk Reduction	Sendai Framework for Disaster Risk Reduction (SFDRR) 2014-2030 (2015)	International (UN)	EA/EbAp; EbA; Eco-DRR	✔	✔
Climate	Paris Agreement on climate change (UNFCCC) (2015)	International (UN)	NBS; EbA; SM/EBM/SFM; Eco-DRR	✔	✔
Biodiversity	Convention on Biological Diversity (CBD) (1993)	International (UN)	NBS; EA/EbAp; GI/BGI; EbA; SM/EBM/SFM; NWRM; Eco-DRR	✔	✔
Urban	New Urban Agenda – Habitat III (2016)	International (UN)	NBS; EA/EbAp; EbA; GI/BGI; EbA; SM/EBM/SFM;	✔	✔
Cross-cutting	European Green Deal	EU	NBS	✔	✔
Biodiversity	Biodiversity Strategy for 2030 (2020)	EU	NBS; GI/BGI; SM/EbM/SFM	✔	✔
Biodiversity	Green Infrastructure Strategy (2013)	EU	NBS; EA/EbAp; GI/BGI; EbA; Eco-DRR	✔	✔
Disaster Risk Reduction	Action Plan on the Sendai Framework for Disaster Risk Reduction (2016)	EU	NBS; EA/EbAp; GI/BGI; EbA; SM/EBM/SFM; NWRM; Eco-DRR	✔	✔
Climate	Strategy on Adaptation to Climate Change (2013, 2021)	EU	NBS; GI/BGI; SM/EbM/SFM	✔	✔
Water management	Floods Directive (2007)	EU	SM/EbM/SFM; NWRM	✔	✔

The analysis illustrates that NBS are increasingly embedded in global and EU policy frameworks as a means to address CCA and DRR challenges. This also indicates the need for NBS assessments for supporting the successful implementation of these policies and recommendations as well as for evaluating the impact of policies and their potential shortcomings.

2 A framework for strategic planning of NBS assessments

2.1 Success factors of NBS assessments

Nature-based solutions play an important and increasing role in both adaptation and disaster risk management. They can serve to increase the resilience of societies to both abrupt and slow-onset climatic and non-climatic hazards, reduce impacts on human health and mortality, and improve overall liveability, well-being and sustainability of both urban and rural areas while also promoting biodiversity and environmental quality (EEA, 2021). As described in Section 1.5, NBS are promoted as preferred or important solutions in a range of global and EU policies. NBS are often seen as no-regret measures for addressing climate and non-climate disaster risks due to the wide range of societal co-benefits they provide (e.g., for physical and mental health, environmental quality and health, biodiversity, aesthetics, recreation, and social cohesion as well as economic benefit) in addition to the primary intended purpose in risk alleviation (CBD, 2019; IPCC, 2012). Their use is therefore often justified even in situations of uncertainty about the projected severity of the climate or other disaster risks and impacts (as so called "no-regret solutions"). Holistic, high-quality assessments of NBS are necessary to reveal, where appropriate quantify, and enhance their provisioning of diverse benefits and promote better understanding and accelerated uptake of NBS.

Several elements, which relate to NBS assessments, have been highlighted as key success factors and limitations in existing literature and are summarised in Table 2. Further success and limiting factors are discussed in the specific cases in Chapter 3. Designing an NBS assessment with the integration of success factors in mind is the basis for the conceptual and practical applications explored in this report.

Table 2: The success and limiting factors of nature-based solutions in adaptation and disaster risk management (Sources: based on Ecofys (2017), (EC, 2020c), McVittie, Cole, Wreford, Sgobbi, & Yordi (2018), Nalau, Becken, & Mackey (2018), Sarabi, Han, Romme, de Vries, & Wendling (2019), Altamirano, de Rijke, Basco Carrera, & Arellano (2021)).

Limiting factors of NBS	Success factors for NBS
Lack of political support.	Supporting plans, acts and legislation. Policy mechanisms are available to address gaps and encourage uptake.
Poor stakeholder engagement and attitudes.	Positive stakeholder engagement and attitudes.
Social and cultural constraints due e.g., cultural preferences for certain aesthetics (what a landscape should look like), risk perceptions relating to different management practices and sense of ownership and place.	Participatory approaches engaging a range of stakeholders, which may include awareness building, giving a voice and co-creation and/or co-management.
Physical and biological constraints due to e.g., degraded ecosystems as a starting point for NBS intervention.	Availability of existing healthy ecosystems or ability to improve degraded ones.
Lack of land or space constraints for implementation.	Adequate scale of implementation and cooperation across landowners. Incentives to encourage cooperation.
Lack of cooperation and consent across landowners and agencies.	Alignment of activities across agencies including shared institutional structures. The use of trusted agents and stakeholder engagement throughout planning and implementation.
Incomplete demonstration of own or comparative benefits (e.g., knowledge gaps on limits and thresholds under which NBS approaches might not deliver adaptation benefits) and unclear cost effectiveness.	Demonstration of multiple co-benefits including multiple ecosystem services. Demonstration of cost effectiveness in comparison to alternatives, including for successful integration with grey infrastructure with demonstrable benefits and leading to optimal planning and design.
Demonstration of effectiveness not tailored to purposes or not at an appropriate scale (e.g., water runoff reduction only demonstrated at plot level but not at catchment scale) and imbalance of knowledge sources underpinning assessments.	Demonstration of effectiveness for the purpose at adequate scale, including adequate monitoring mechanisms.
Gap of knowledge between private benefits to individual entities and broader social costs and benefits for communities. Time lags in achieving and observing benefits.	Demonstration of both private and social costs and benefits over short- and long-term.

Limiting factors of NBS	Success factors for NBS
Evidence is context specific and often not transferable and is not shared.	Existing knowledge and/or ongoing research and monitoring with common indicators and innovation and demonstration projects (incl. reporting standards). Established knowledge sharing mechanisms, education and training.
Lack of finance for implementation of NBS (e.g., for land acquisition/compensation) and maintenance.	Availability of finance. Multiple sources of finance linked to multiple benefits and multiple ecosystem services. Early budgeting and assignment of funds and responsibilities to meet maintenance needs.
Difficulties in NBS tendering process (e.g. lack of knowledge on how to present a convincing business case for NBS, lack of track record, lack of (experienced) suppliers, path dependency favouring engineered solutions).	Engagement with NBS technical and NBS economics experts to gather supporting evidence for robust business case development. Early cross-departmental collaboration including engaging with procurement and finance units. Consideration of alternative procurement and delivery mechanisms outside own procurement.

It is evident that assessments that can demonstrate to decision-makers NBS effectiveness at the relevant scale can also facilitate cross-departmental collaboration, organize existing knowledge and create new evidence of social, environmental and economic costs and benefits, and recognise a multitude of co-benefits as well as open access to funding and financing.

2.2 A Step-wise framework for designing NBS assessments

In order to structure and guide the processes, which need to take place when designing a well-planned NBS assessment, we present a Step-by-Step framework (Figure 3). The steps in the framework examine the specific purposes for which NBS assessments can be undertaken in the CCA and DRR contexts, the additional synergistic purposes these assessments may serve as well as the key methodological characteristics that guide the assessment design and the final choice of the best suited approach.

The framework follows four steps:

Step 1: Identifying NBS assessment purposes and goals, including outcome needs - examined in further detail in Section 2.2.1;

Step 2: Defining assessment characteristics as guided by the purposes - outlined in Section 2.2.2;

Step 3: Selection of elements to be included in the assessment, which may be technical, environmental, social or economic - see latter part of Section 2.2.3; and 2.2.4;

Step 4: Choice of the assessment approach (or several approaches) based on all of the above deliberations (see Section 2.2.5);

Data and resource considerations need to be part of every step of the decision-making and will in turn be informed by the decisions made, especially on the purposes, goals and output needs.

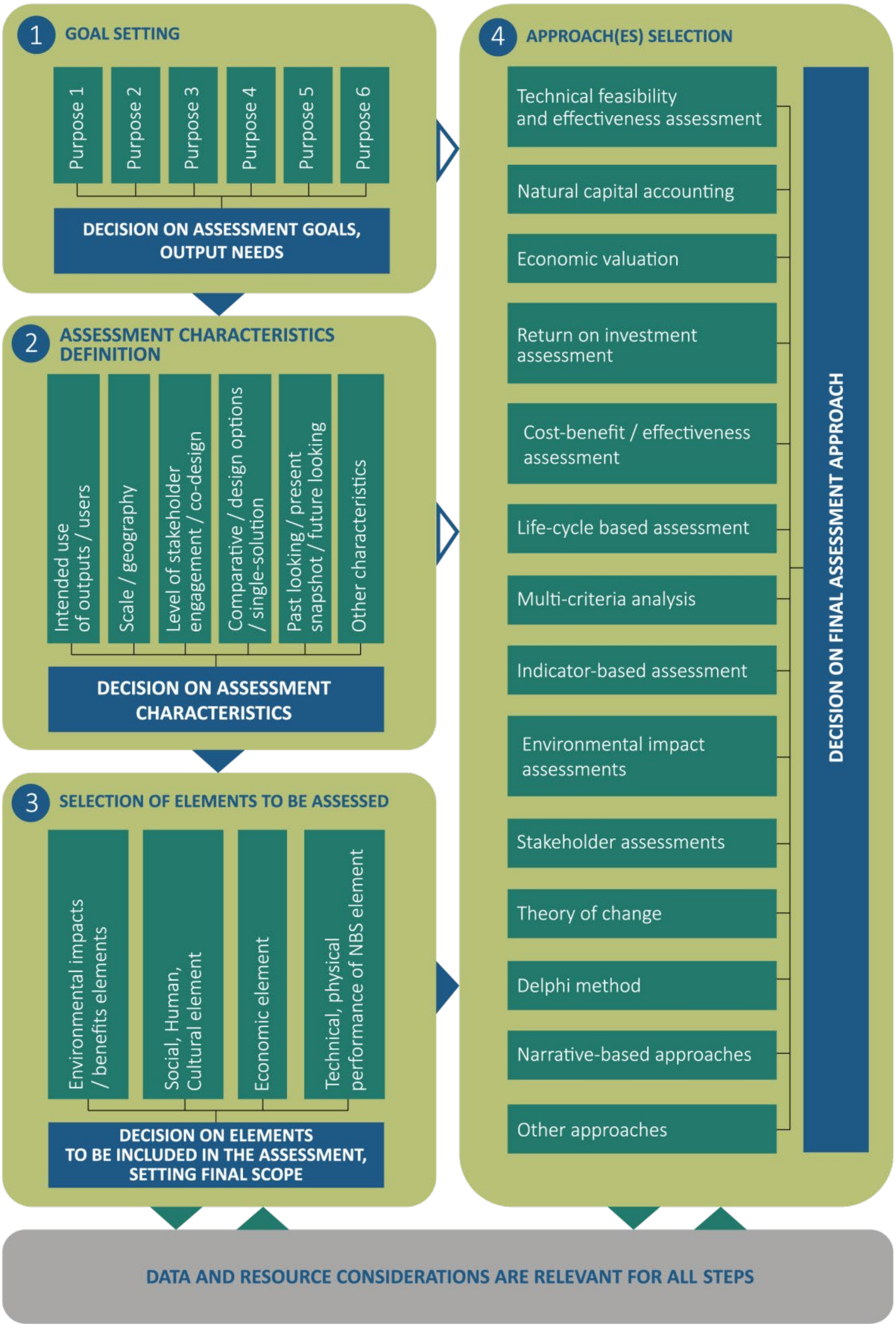
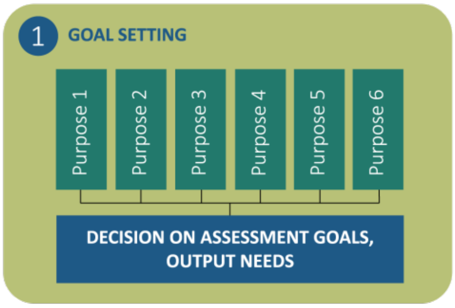


Figure 3: Framework for NBS assessment design process (Source: own elaboration partially inspired by EC (2021a) Evaluating the Impact of Nature-based Solutions: A Handbook for Practitioners, Chapter 6).

It needs to be noted that in many cases the various elements considered in this process will not be cleanly delineated and neatly fitting in defined separate categories. Instead, they may be overlapping, combined or embedded within each other and therefore each NBS assessment design will have its own unique pattern.

2.2.1 STEP 1: Purpose and goal setting



Early and clear definition of the purpose for evaluating NBS in the context of a broader policy-making and implementation cycle is important to determine the type and level of complexity of the assessment needed. A multitude of questions can be answered, such as: Which CCA or DRM planning and implementation cycle Step (see Figure 5 and Figure 6) and which decisions will the assessment support? What is the information gap that the assessment should address? Who are the intended users of the information and what are their information needs? How will the outcomes of the assessment be fed into the decision- and policy-making process? What additional purposes might the assessment help to benefit?
The definition of the purpose starts with identifying the entry point(s) in the CCA or DRM cycle, which the assessment will serve.

2.2.1.1 Entry points in adaptation to climate change cycle

The need for assessments of the potential and planned or implemented adaptation measures, including those based on NBS, arises in several Steps in the adaptation cycle. Based on the adaptation cycle defined by the EU Guidance for developing adaptation strategies (EC, 2013) as well as the Adaptation Support Tool (EC/EEA, n.d.a) and Urban Adaptation Support Tool (EC/EEA and Convenant of Mayors, n.d.) on Climate-ADAPT portal (EC/EEA, n.d.b), the key entry points have been illustrated in Figure 5 and are the following:

- CCA cycle Step 3: Identifying adaptation options;
- CCA cycle Step 4: Assessing adaptation options;
- CCA cycle Step 5: Implementing adaptation;
- CCA cycle Step 6: Monitoring and evaluation (may involve continuous or regular monitoring and assessment, which is carried out during Step 5 as well).

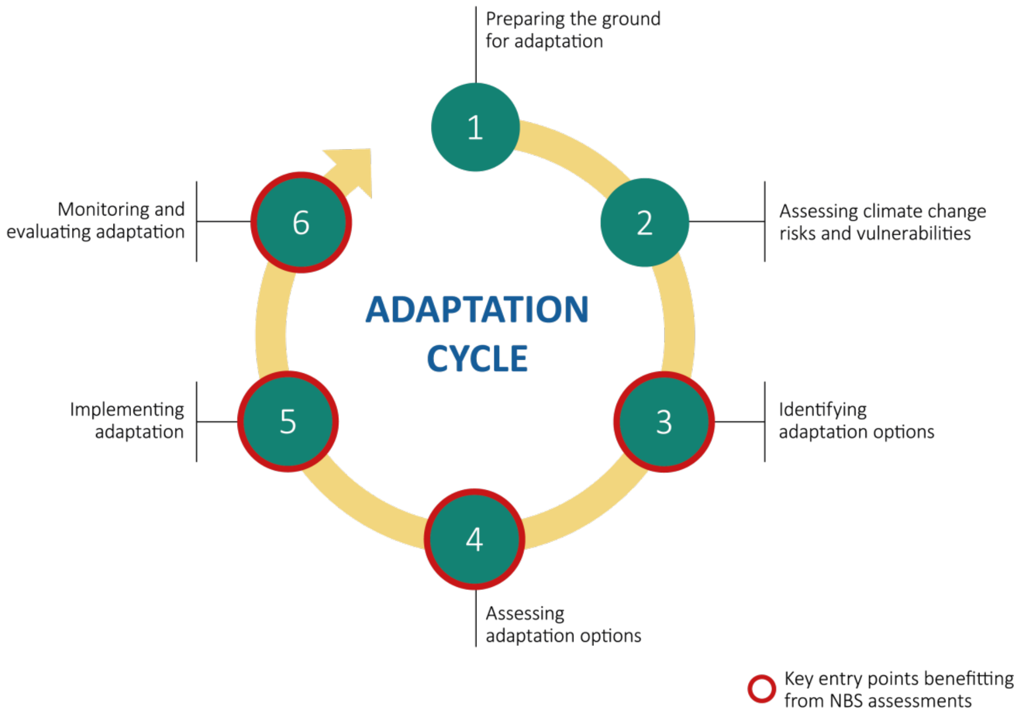


Figure 5: Entry points for NBS assessments in the adaptation planning and implementation cycle.

2.2.1.2 Entry points in disaster risk management cycle

The EU's Sendai Framework Action Plan (EC, 2016) identifies the fostering and implementation of ecosystem-based approaches to DRR as one of its priorities and foresees the development of an assessment framework and guidance for developing Green Infrastructure in cities specifically. This action is planned to support the Sendai Priority 3 "Investing in disaster risk reduction for resilience". In a clear overlap with the adaptation to climate change community, NBS are seen as key components of building resilience in DRM, with the difference being in the scope of risks being addressed.

The DRM cycle differs from the adaptation cycle in that it is centred around the occurrence of disasters and therefore is split into pre-disaster, disaster response and post-disaster stages (see Figure 6). NBS are mainly considered, assessed and implemented in the pre-disaster stage as prevention measures; however, their effectiveness should ideally also be assessed post-disaster. On this basis, the entry points for NBS assessments in the DRM cycle are:

- Planning and implementation of NBS as part of prevention approach;
- Assessments as part of ongoing maintenance and operation of NBS solutions;
- Post-disaster evaluation of NBS effectiveness and performance and
- Post-disaster assessment of the need for NBS improvements or additional NBS.

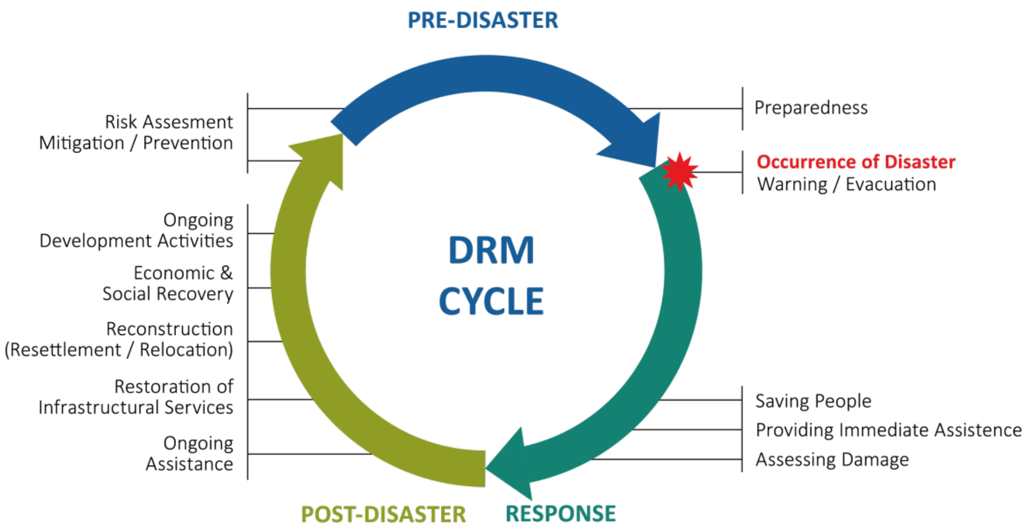


Figure 6: Disaster risk management planning and implementation cycle and entry points for NBS assessment.

2.2.1.3 Purposes of NBS assessments in CCA and DRR contexts

With (a) clear entry point(s) in mind, the specific purpose of the assessment can be further defined and refined based on the participating or targeted stakeholder needs. The typical purposes for NBS assessments in both adaptation and DRM cycles are similar and can be categorised as ex-ante, operational phase and ex-post assessments based on their timing in relation to an NBS project and its implementation. In relation to the NBS project implementation cycle outlined by EC (2021a) (on page 36, Fig. 1 and Fig 3), ex-ante assessments take place during stakeholder engagement, assessment, project and action planning, while operational phase assessments are mostly undertaken during NBS implementation and ex-post assessments as part of the monitoring and evaluation.

Purposes for ex-ante assessments (CCA cycle Steps 3 and 4 and prevention phase in DRM cycle)

- Providing a robust evidence base for informing the project's holder(s) about the benefits and trade-offs of **choosing between different options** of measures for adaptation/disaster prevention (including comparisons with conventional, grey and other measures).
- **Assessing the technical effectiveness of NBS for risk reduction and resilience increase** in support of the engineering technical design (including as design scenarios), also in comparison to other measures.
- **Understanding the full range of environmental, economic and societal impacts and benefits of NBS** going beyond the adaptation/DRM benefit, and to identify pathways for enhancing synergies and reducing trade-offs.
- **Assessing the expected costs of implementation and maintenance** in support of budget planning
- **Assessing project economic parameters** such as the net present value, cost-effectiveness and cost-benefit ratios alone or in comparison with other measures **to build the business case for NBS implementation.**
- **Provide data and messaging for communication** on the benefits of NBS as adaptation/DRM measures – including to aid stakeholder awareness, participation and buy-in (credibility, legitimacy, salience).
- Assessments of NBS potential for **carbon or biodiversity credit/offset or compensation schemes.**
- Assessments of NBS projects **to build a financial case for attracting sustainable private sector finance for adaptation/DRM**, based on applicable sustainable finance frameworks[3] and their criteria.

Purposes for operational phase assessments (CCA cycle Step 5 and 6, ongoing operation and maintenance phases in DRM cycle)

- Continuous or regular monitoring and assessments of the technical and economic performance of the implemented NBS (may be expanded to include broader environmental and social effect observations):
  - for **calibration purposes;**
  - to **build understanding and evidence base on the functioning of NBS;**
  - for **verification of the design or identification of design improvements and possible scale-up;**
  - for **assessing and reporting the expenditure and benefits ratios, including for supporting maintenance cost budgeting.**
- **Assessment of the asset value** of the NBS for inclusion in balance sheets.

Purposes for ex-post assessments (CCA cycle Step 6, post-disaster evaluation phase in DRM cycle)

- **Assessing the effect achieved** of NBS on the climate impact/risk reduction (the resilience effect) – the change in the system as compared to the baseline before – including to aid the overall evaluation of adaptation/DRM strategy or plan implementation.
- Assessing the **return on investment made.**
- Evaluating the **full societal benefit achieved** across the full range of benefits, costs and dis-benefits of NBS.
- **Knowledge base for informing future designs, funding and implementation approaches** for NBS as adaptation/DRM measures.

It is evident that NBS assessments can serve a multitude of purposes across CCA and DRM cycles starting from the early phases of planning through to the post-implementation monitoring and evaluation, outputs of the latter may further feed in the planning of new or improved NBS thus starting a new cycle. In line with the defined purposes, the assessments may be more technical or social and environmental benefit oriented, focused on the economics or any combinations of these (see Section 2.2.2). Having a full up-front clarity on where and how the NBS assessment or a series of assessments will fit in the full CCA/DRM cycle provides the advantage of strategic early planning to ensure synergies between the assessment efforts and provide continuous flow of information as needed in support of CCA and DRM objectives.

[3] Such as the EU Sustainable Finance Framework, including the EU Taxonomy of sustainable economic activities: https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance_en

Another way to increase the resource-effectiveness of an NBS assessment is the consideration of other synergistic purposes the assessment may serve outside of the CCA/DRM realm, which is addressed in the following.

2.2.1.4 Synergistic purposes and benefits of NBS assessments

In the specific context of CCA and DRR planning and implementation, the assessments of NBS may primarily focus on their suitability, performance and cost-effectiveness to address specific climatic and non-climatic hazard risks. Nevertheless, an early and deliberate identification of other synergistic purposes these assessments can and will serve is beneficial to achieve a broader use of the assessment outcomes in various policy and decision-making areas and a more efficient use of resources devoted to the assessment. Such integrated, multi-purpose assessments require inclusion of a wider scope of assessment elements (see Section 2.2) and can reveal a broader range of benefits (and trade-offs) than single-purpose assessments. This may provide a richer context and evidence base for decision-making about NBS. Integrated assessments are also likely to require more extensive and/or intensive stakeholder participation, e.g., the representatives and data holders from the synergistic fields of practice). The synergistic benefits of multi-purpose NBS assessments may include the following:

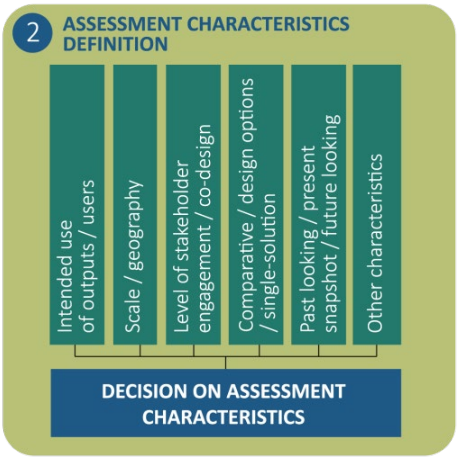
- To generate knowledge **supporting biodiversity and other environmental management policies** and implementation (including conservation, water and waste management, soil conservation, air water and noise pollution control and reduction).
- **To integrate climate change mitigation** benefits in the solution (e.g., reduced emissions, carbon storage and sequestration).
- To provide **data and metrics required for carbon farming, carbon removals and storage certification.**[4] **or biodiversity credit, offset or compensation schemes** present in various European countries.[5]
- To improve the understanding of the **benefits related to physical and mental health** and how to best design NBS to maximise these in addition to the main adaptation purpose.
- **To account for and incentivise the consideration of social benefits** (e.g., due to recreation opportunities and creation of social interaction spaces, increased equality in access to green space).
- To explore the integration with **food production/agriculture benefits.**
- To assess the potential impact of NBS implementation on **land and real-estate value changes**, or land-use related opportunity costs.
- **To inform spatial and urban planning policies**, such as those addressing place-making, regeneration, brownfield remediation and similar activities.
- To understand and **plan for other cascading effects**, such as energy efficiency, sustainable mobility, and local economic activity.
- To build a **broader, more multi-faceted business case for investment**, possibly involving several blended funding sources, also including private sector.
- To **illustrate new economic opportunities** and green job creation.
- To understand the **cost-bearing and benefit distribution between different stakeholders** and identify misalignments that need to be addressed.
- To **integrate into environmental-economic accounts** aligned with the UN SEEA-EA standard (SEEA, 2021).
- To illustrate **NBS contributions to local Sustainable Development Goals'** implementation and overall sustainability strategies.
- **To contribute to the state-of-the-art** and increase the evidence/knowledge base on NBS. To generate local knowledge on NBS that can be used to access European Union, national or local sector funding.

[4] For more on EU Carbon farming policy see: https://ec.europa.eu/clima/eu-action/forests-and-agriculture/carbon-farming_en

[5] For country policies in this regard see: https://biodiversity.europa.eu/countries

These synergistic benefits have been summarized from expert group inputs, literature overview in the EEA report on NBS in Europe (EEA, 2021) and a global survey of green infrastructure practitioners[6] as well as authors' expert experience, however there may be examples of other synergistic benefits, especially those arising in specific local contexts.

2.2.2 STEP 2: definition of assessment characteristics



In light of the wide variety of purposes NBS assessments can serve, the choice of an assessment approach needs to be matched to its intended purpose. To do that, it is first necessary to identify the key assessment characteristics and output types required for fulfilling the purpose (Step 2, Figure 3), before decisions on the elements to be addressed by the assessment (Step 3, Figure 3) and on the choice of the specific approaches (Step 4, Figure 3) can be made. Here we outline the questions that need to be considered and answered for a range of key assessment characteristics.

Key aspects to consider for defining the assessment characteristics include:

Intended use of assessment outputs and their users
- Will the assessment serve one or multiple purposes (see Section 2.2.1.3)?
- Where in the adaptation/DRM planning and implementation cycle the assessment is required (see Section 2.2.1)?
- Based on the purpose, which economic, environmental, social or multidisciplinary aspects need to be included in the assessment?

For determining the intended use of assessment outputs, it is important to have a good understanding of who are the users of the assessment output and what decisions the NBS assessment should inform.

Scale and geographical context
- What is the scale of the assessment – plot scale, neighbourhood, city, regional, national or international scale?
- What are the local specificities and do they require high level of adaptation of the approach to the particular local decision-making context?

To address these considerations, a scoping analysis including site visits and stakeholder consultations can help clarify the need for adaptation and DRR within the specific local context. This includes information on site location including its economic, environment, social and institutional characteristics, climate change impacts, as well as possible NBS options that are considered (see Table 3 in Green-Gray Community of Practice (2020)).

Level of stakeholder engagement and participatory process of co-creation
- Should the assessment be expert or stakeholder driven or both? How are different knowledge types included and integrated in the assessment (e.g., indigenous and local knowledge, citizen science, expert knowledge etc.)?
- Which stakeholder concerns need to be included?

[6] Unpublished. Romanovska, L: Survey on urban green infrastructure in policy-making and practice: knowledge gaps and barriers.

- Which level off stakeholder participation is the most appropriate? Is a smaller scale consultation sufficient, or should a collaborative co-creation and co-management approach be pursued?

An inclusive and transparent assessment process can be critical for building credibility of the both the assessment process and output, which is vital for ensuring the use of the generated information in decision making.

Comparative approach for assessing advantage and disadvantages to conventional options

- Does a comparative design of the assessment (e.g., compare against grey alternatives, between different NBS, between different locations or characteristics of the same or similar NBS) help in highlight particular characteristics of NBS, which are of relevance for decision making (e.g. cost effectiveness when compared to other options)?

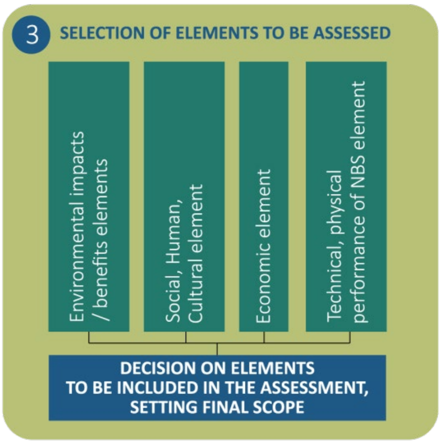
NBS involve different degrees of anthropogenic input ranging from little or no input (ecosystem conservation) to high input (creating new ecosystems) (Eggermont, et al., 2015). When considering NBS options serving as green infrastructure, the characterisation of NBS options can be assessed according to the degree of green-grey infrastructure (see Figure 8). The conceptual representation of NBS options along the green to grey gradient helps in identifying, comparing and communicating assessed options.

Figure 8: Green-Gray Community of Practice (2020). Practical Guide to Implementing Green-Gray Infrastructure (Available at: https://www.conservation.org/projects/global-green-gray-community-of-practice).

Time perspective: past looking, present snapshot, or future looking

- Does the assessment need to be past-looking, current snapshot and/or forward-looking in time, or perhaps continuous?
- If the assessment is evaluating progress or performance over time, what are the requirements for establishing a baseline or reference level?
- Should the assessment involve scenarios and if so, should it involve one or multiple scenarios?

2.2.3 STEP 3: selection of elements to be assessed



A key decision in designing an NBS assessment is the on the range of the thematic elements to be addressed by the assessment. They may include the environmental, social (and cultural), economic and/or technical performance elements. The following questions may aid the decisions for choosing the scope of elements to be included in the assessment and the further detailing of them.

Environmental element addressing positive and negative environmental impacts

- Which environmental impacts (positive and negative) have to be considered and assessed?
- Does the NBS measure have an impact on ecosystems and what consequences does this have for biodiversity, water cycle, soil quality, erosion, noise or other environmental variables?
- Which ecosystem services are affected and how?
- Who are the stakeholder groups impacted by such environmental impacts?

Environmental impact assessments are often required by law with guidance on certain environmental variables to be addressed. For assessing the environmental impacts of NBS it is in particular important to focus on how the NBS measure impacts biodiversity, ecosystems and the provision of ecosystem services as these are central characteristics of any NBS measure. In particular the assessment of impacts on the provision of ecosystem services requires a focus on who are the potentially affected stakeholders?

Social, human, cultural element addressing societal impacts

- What are social, human and cultural aspects that that are impacted by an NBS measure?
- Who is benefiting from an NBS measure and who is negatively impacted and bearing the cost?
- Does an NBS enhance human wellbeing? If so, what are these benefits and how can the NBS measure be designed for serving multiple purposes besides adaptation and disaster risk reduction?
- Does a NBS measure have adverse impacts on any particular stakeholder groups? If so, what are these negative impacts and how can they be avoided?
- Does the implementation of an NBS measure have a risk of increasing inequalities among stakeholder groups?
- How does the NBS measure impact the human relationship with nature?
- Are any indigenous or traditional management practices impacted by the NBS measure?

Economic element addressing costs and benefits

- Which dis-benefits and costs related to the NBS implementation need to be considered (see Table 5 in Green-Gray Community of Practice (2020))? For example, planning and design costs, opportunity and transaction costs, capital costs involved in financing the NBS measure, costs involved in implementation (e.g., construction costs), costs related to monitoring, maintenance, and management of a NBS measure.
- Are there any long-term uncertainties from which further costs could evolve?
- Does the maintenance of the NBS measure and the related cost also enhance its resilience to climate change for ensuring its sustainability?
- Which benefits related to the NBS implementation need to be considered? Are there synergies of the NBS measure with other purposes or societal goals beyond adaptation and DRR?

Technical, physical and performance of NBS element and types of outputs relevant for demonstrating NBS effectiveness

- Which information on the NBS option is most relevant for decision making: technical effectiveness information (e.g., cooling effect of green space, rainwater retention, etc.), environmental information (e.g., biodiversity benefits), social information (e.g., number of inhabitants benefiting from an NBS measure) or economic information (e.g., electricity costs saved, damage costs avoided, etc.)?
- What are the required output types – quantitative, qualitative, visual, etc.?
- Which output metrics are important for the purpose?

A central characteristic for the performance of an NBS is its provision and strengthening of ecosystems and their provision of ecosystem services for CCA and DRR. Assessments of natural capital including ecosystem services can include both monetary and biophysical indicators on, for example, provisioning services (e.g., goods harvested such as agricultural products, timber and non-timber forest products), regulating services (e.g., water quality, temperature, carbon sequestration and storage, erosion control, pollination), and cultural services (e.g., recreation, tourism, etc.).

2.2.4 Data and resource considerations

A clear definition of the purpose of the NBS assessment (Step 1), its characteristics (Step 2), and thematic elements (Step 3) is a prerequisite for determining what kind of data is required to inform decision making. Thereby, it is important that decision makers regard the generated data and information to be credible, relevant and legitimate for informing decision processes (Sarkki, et al., 2015). It is not always necessary to use the most detailed and sophisticated methods for generating credible, relevant and legitimate information. If similar assessments have been conducted elsewhere, experiences and information can possibly be transferred across sites (e.g., data on the cooling effect of trees or benefit transfer of economic information related to urban green) using secondary data. However, NBS effectiveness often depends on the specific local context, primary data on key indicators might be needed. Given that resources are limited, it is important to achieve a balance between credibility, relevance and legitimacy of the required data and information. This also has to be considered when choosing the assessment approach (Section 2.2.5).

2.2.4.1 Requirements for the input and output data

- Are there specific requirements for input and output data quality for the purpose? How robust and reliable do the outputs need to be? (See Box 1)
- What level of detail and spatial and temporal data resolution is necessary?
- How does the assessment need to account for and deal with uncertainty and incomplete information; including future socio-economic and climate change scenarios and their impacts on NBS?
- Can information and experiences from other sites be transferred and applied for informing decision making? Or are in-situ assessments for generating primary data required?
- To whom and how do the results need to be communicated. Which information is the most relevant for stakeholders?

The data and expertise needed for achieving the needed outputs and its availability will heavily impact the choice of the assessment method.

Box 1: Data related choices

Ideally, there should be a balance between credibility, relevance and legitimacy of the data with regards to its use for informing decision making (Sarkki et al. 2015). These aspects need to be considered when defining data requirements. While the data-related choices below are presented as dichotomous, in many cases there will be a need of combining the different options, for example, by using numeric and narrative-based and visual data instead of choosing just one type.

1. Qualitative vs. quantitative information.
2. Quick and rough vs. slow and detailed assessments.
3. Coarse vs fine grained data (granularity, resolution, accuracy).
4. Spatial vs non-spatial data.
5. Large scale vs small scale.
6. Data acquisition pattern: continuous vs. demand-driven vs. one-off vs. Periodic.
7. Direct measurements (e.g., in-situ sampling, on the ground monitoring) vs. remote sensing vs. off-site experiments vs. secondary data transfer vs. crowd-sourced data (e.g., citizen science).
8. Numeric versus narrative versus visual information.
9. Data processing level: raw data vs. quality-controlled data vs processed data.

Source: based on Annex of the Evaluating the Impact of Nature-Based Solutions: A Handbook for Practitioners (EC, 2021a)

2.2.4.2 Available resources and influence on assessment design

- What resources are available for carrying out the assessment in terms of personnel and their skills, available tools and funding?
- How much time can be devoted to the assessment? By when is the information needed in order to be relevant for the decision-making process?

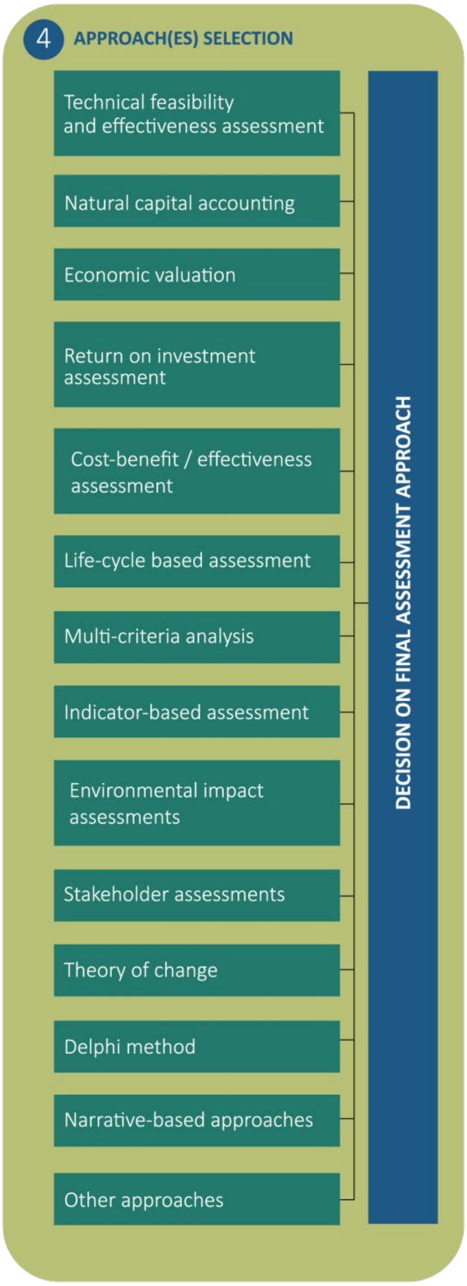
In most cases, resource requirements will correlate with the level of detail, quality and thoroughness of the assessment as determined by required inputs and outputs. Both data and resource considerations need to be part of each Step of the decision-making when designing an NBS assessment to ensure the right balance of resource use and comprehensiveness of the outputs.

In many cases, the overarching purpose will not determine all of the key characteristics of the assessment (i.e., the answers to all of the above questions). This reflects the fact that the same type of assessment may be carried out for the same purpose but with different underlying characteristics: varying timeframes, a differing level of detail and a range of different outputs. For example, for the overarching purpose of comparing the different NBS solutions addressing pluvial flood risk in a city, the decisions may be made that the assessment will be forward-looking on a decadal timescale, assessed on the neighbourhood level with a robust uncertainty assessment, and should produce primarily technical effectiveness data as outputs. Or alternatively, it may require yearly resolution for the next 30 years, carried out on a plot scale and besides the technical focus will also include economic metrics as outputs. It is thus rather the careful consideration of the main purpose in combination with more detailed case-by-case needs and requirements and the corresponding choices that will present the full picture characterising the assessment needs.

Section 2.2.2 of this report proposes a conceptual framework that can guide a decision-maker through the Steps of designing an assessment which is fit for purpose.

Building up on the previous discussion in Sections 2.2.1 to 2.2.4 and inputs from case studies discussed in more detail in Chapter 3, **Annex 1** compiles the list of purposes for NBS assessments along with key characteristics the assessments for these purposes typically require (but may vary, sometimes significantly). Annex 1 likewise maps the assessment approaches that may be useful to fulfil each of the purposes (the methodological approaches are discussed in more detail in Section 2.2) as well as links to real-world case examples.

2.2.5 STEP 4: Approaches for NBS assessments



(EC, 2021a) As discussed in the previous Section, the design of assessments of NBS for CCA and DRR strongly depends on the particular purpose and information needs identified for a given decision-making context. This includes information on the adaptation or DRR objective (e.g., flood risk reduction), the environmental and social-ecological context, and costs and benefits resulting from the intervention. The following Sections provide a brief overview of several possible methodological approaches for NBS assessments, which may be matched with the identified purposes, needs, required assessment characteristics and scope of thematic elements. Each of the approaches summarised in this Section may in themselves present a specific method or a combination of methods or may be implemented by using different embedded methods. The choice about the right combination of methods and the overarching approach may not always be immediately apparent and discussion among the project team, experts and stakeholders frequently referring back to the decisions made in the previous Steps may be needed.

The approaches that are likely to lead to successful outcomes if, as recommended by the NBS Handbook, they (EC, 2021a) follow these guiding principles:

1. Scientifically sound.
2. Practical and straight-forward.
3. Use reference conditions and baseline assessment, including monitoring (for performance assessments).
4. Align with policy principles and reporting obligations.
5. Based on a transdisciplinary approach (especially important when targeting multiple purposes as suggested in Section 2.2.1)

These principles, however, also indicate that the process of designing assessments involves addressing trade-offs between the level of detail the assessment needs to generate as output versus the effort and resources available. This includes, for example, ensuring the scientific robustness of assessment outcomes while at the same time aiming for a "practical and straight-forward" assessment approach in the sense of being doable with the available resources, skills and expertise. Assessments should also align with the policy context and may require transdisciplinarity, involving experts from various disciplines and sectors, but within the same resource limitations. In this process of determining the assessment design, it is critical to consider the purpose of the assessment as outlined in Section 2.2.1. This will help in achieving an adequate balance between assessment complexity and the generation of assessment outcomes that are useful for the intended purpose and possible within the available resources.

The main groups of available approaches for assessing key adaptation and DRR objectives as well as their multiple benefits in different dimensions include those presented in Table 3. Please note that they are not mutually exclusive and are often combined with or nested within one another. The list is likewise not exclusive and there may be other approaches suitable for a specific context and purpose.

Table 3: Approaches for assessing NBS for climate change adaptation (CCA) and disaster risk reduction (DRR) and their multiple benefits.

Approaches for assessing NBS for CCA and DRR and their multiple benefits	Further resources and guidance on the application of the approach
Ex-ante **technical feasibility and expected effectiveness assessments** (which may be based on literature, inventories, sensor and monitoring data, modelling-led, or based on a participatory process of jointly defining NBS objectives and key performance indicators).	Identification and assessment of key performance indicators (KPIs) related to the expected hazard, exposure and vulnerability to be addressed by the NBS (e.g., area and number of households likely to benefit by NBS implementation. See Chapter 2 by Skodra et al. in (EC, 2021a) for further guidance on NBS indicators.
Stock-taking/accounting of natural capital and ecosystem services (mapping, GIS, inventories) for demonstrating ecosystem assets and the flows of benefits (ecosystem services) provided by NBS.	Vysna et al. (2021) provide guidance for developing ecosystem accounts within the EU context, including ecosystem extent accounts, ecosystem condition accounts and ecosystem service accounts.
Economic valuation of specific benefits, in particular through the use of environmental economics methods: contingent valuation/stated preference (e.g., willingness to pay, trade-off game, costless-choice), revealed preference (e.g., travel-cost method, hedonic pricing, preventive expenditure, preventive markets, etc.), benefit transfer and others.	Based on the assessment of case studies Emerton (2017) provides an overview of approaches to valuing the benefits, costs and impacts of ecosystem-based adaptation measures. The practical guide on assessing and implementing green-gray infrastructure for adaptation and disaster risk reduction includes an overview of approached for economic valuation of benefits, cost-benefit analysis and assessing return on investment with the aim of guiding decision making on infrastructure investments (Green-Gray Community of Practice, 2020).
Cost-benefit assessments and cost-effectiveness assessments.	
Return on investment assessments (net present value, internal rate of return, payback time and others) and how benefits are delivered over time.	
Holistic **life-cycle-based impact assessments** (life-cycle assessments (LCA), life-cycle costing, social-LCA, life cycle sustainability assessments) for a systemic understanding when and where impacts occur and who is impacted along the process of establishing and maintaining NBS.	The guide by the UNEP/SETAC Life Cycle Initiative provides and overview of identifying and using life cycle impact assessment indicators (UNEP, 2016).
Multi-criteria analysis (stakeholder or expert based) for weighing and comparing different NBS impacts.	The handbook for practitioners on evaluating the impact of nature-based solutions by the European Commission provides a detailed overview of indicators and methods used in EU projects for assessing NBS (EC, 2021a). See also the appendix for further details on methods (EC, 2021b).
Indicator-based assessments with a focus on a specific set of indicators, not necessarily involving a systems perspective.	The handbook for practitioners on evaluating the impact of nature-based solutions provides a detailed overview of indicators and methods used in EU projects for assessing NBS (EC, 2021a).
Environmental impact assessments can be required for complying with procedural and legal standards for assessing potential environmental impacts from the implementation of NBS measures. This can also contribute to generating credible and legitimate information.	The implementation of public and private projects often requires an environmental impact assessment before the implementation of the project (EU Directive 85/337/EEC).
Stakeholder assessments (interviews, surveys, focus groups, stakeholder seminars, public consultations), e.g., for understanding how stakeholders benefit from or are impacted by NBS or for informing an inclusive and participatory assessment design.	Zingraff-Hamed et al. (2020) present an approach for identifying stakeholders that should be involved in the co-creation of NBS based on experiences from case studies within the EU projects RECONECT and PHUSICOS. Wehn, Rusca, Evers, & Lanfranchi (2015) present an approach for identifying opportunities for supporting greater engagement and participation of citizens in decision-making on DRR and during different phases of the disaster cycle (prevention, preparedness, response, and recovery).
Theory of change can provide a framework for strategically integrating NBS assessments into decision making on adaptation and DRM.	Stafford Smith (2020) provide guidance on how to use Theory of Change for improving project outcomes that can enable transformational change.
Delphi method is an iterative and participatory method for evaluating expert-based knowledge, which has been applied for decision-support and assessing knowledge needs for NBS implementation.	Mukherjee et al. (2015) guidance on using the Delphi method in ecology and conservation, which can also inform NBS. Grace et al. (2021) describe the use of a Delphi process for assessing knowledge needs for implementing NBS in Mediterranean islands.
Narrative-based approaches (e.g., storylines) can help to integrate different stakeholder perspectives and support the co-design of NBS assessments.	Welden, Chausson, & Melanidis (2021) highlight the importance of framing NBS and making explicit the co-dependence of people and nature, which can support transformative change. Davis, Gerdes, Naumann, & Hudson (2015) provide examples for evidence-based narratives for NBS.

Figure 11 maps these various methods/approaches based on whether they are primarily data-led or stakeholder-led and which assessment elements they most commonly focus on: technical, economic, or environmental and social impact.

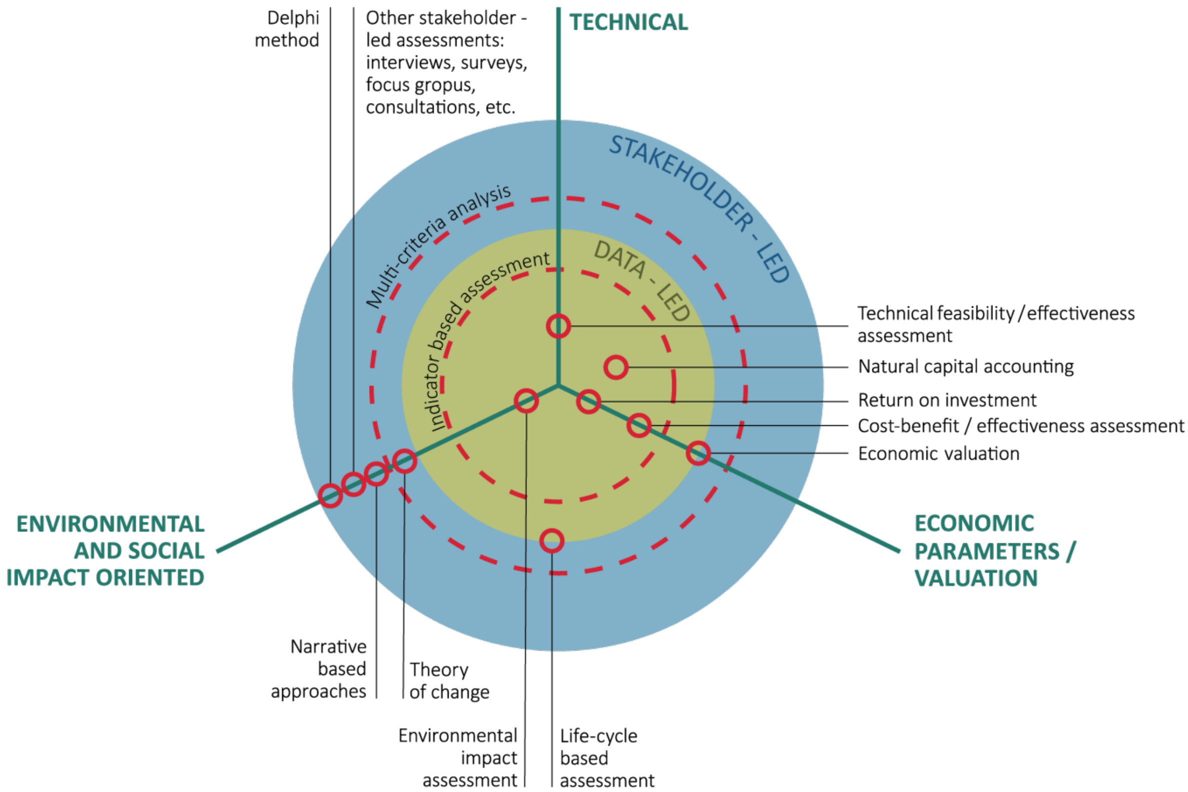


Figure 11: Mapping of NBS assessment approaches based on the elements they focus on and data- or stakeholder-led methodological orientation.

Annex 1 connects these approaches with the purposes identified in Section 2.2.1 and lists the case studies where the approach has been applied.

While in broad terms NBS assessment approaches may be mapped based on their stakeholder-led or data-based orientation and common use focus on either the technical aspects of NBS, or the environmental/social impact or economic parameters, in reality many of them may derive their inputs from ‘either/or’ or ‘both’ various data sets and stakeholder inputs and lead to a range of different outputs. Therefore, the definition of purposes, characteristics and elements of the assessment is likely to arrive at not one, but several approach options, with the final choice depending on such considerations as data and know-how availability and preferences of internal or external end-users.

The following Chapter explores how NBS assessments have been designed and carried out in real life situations and various contexts across Europe and illustrates how the various elements discussed in Chapter 2 have been considered and addressed.

3 NBS assessment in practice

3.1 Case study aims and methodology

There is a growing evidence base at the European level in terms of practice and guidance on assessment and monitoring of NBS projects, i.e., the report 'Evaluating the Impact of Nature-Based Solutions: A Handbook for Practitioners' (EC, 2021a) and the research and demonstration investments into NBS interventions within Horizon 2020 and Horizon Europe-funded research projects (EC, 2020b). This Section adds to the growing evidence by analysing the types of assessments and fact-checking of how past and on-going NBS case studies have applied such an approach and what role assessments have played in the decision-making.

The selection of NBS case studies for this specific analysis is based on a previous screening of European NBS examples where a total of 97 NBS cases in 107 locations across Europe was considered (EEA, 2021). These 97 cases were identified and extracted from the following NBS platforms: Climate-ADAPT (European Climate Adaptation Platform); Natural Hazards — Nature-based Solutions; Naturvation (Nature-based Urban Innovation); NWRM (Natural Water Retention Measures); OPPLA (platform for nature-based solutions); Panorama (a global project on mainstreaming ecosystem-based adaptation); and weADAPT (a collaborative platform on climate change adaptation issues). Different sector and thematic areas were reviewed, including water management, forests and forestry, agriculture (including agroforestry), urban areas, coastal areas and mountains. All NBS cases retained in the screening address various societal challenges using NBS for CCA and DRR. The breakdown of cases by country and sector/thematic area is presented in Annex 3 of EEA (2021).

The analysis of cases in EEA (2021) focused on providing an overview of the type of methods applied, NBS measures implemented, innovative features of the projects and wider applications of the results and lessons learned. This report looks at the use of assessment frameworks and the context in which the assessments are chosen, designed and implemented. Notably, the analysis seeks to understand the following components for each case study:

- the main adaptation/DRR purpose/thematic area of a NBS case as well as the main non-adaptation related benefits provided by the NBS (used as main criterion on categorizing, see Section 3.2);
- if projects have conducted a qualitative and/or a quantitative assessment of the NBS, either before, during or after its implementation;
- what kind of indicators have been assessed in the different types of assessments and projects;
- for those projects that did not conduct an assessment, what were the circumstances of not carrying out an assessment.

This report also looks more in depth at 9 case studies to understand:

- the source of funding for NBS and provisions for long-term monitoring;
- the type of assessment methods applied and key characteristics;
- the purpose of assessments and key determining factors;
- the usefulness of assessment results and barriers and usefulness;
- the inclusion of social vulnerability in assessments and involvement of stakeholders.

A two-Step approach was applied. First, a short email survey was sent to the screened cases from EEA (2021) where a contact person could be identified. Out of the original 97 cases, it was possible to identify contacts in 85 of the cases. The purpose of the email survey was to determine what type of qualitative and/or quantitative assessment has been applied (pls. see Annex 2 for the email survey). Second, an in-depth interview was conducted with nine selected case studies during August and September 2021 (see Annex 3 for survey instrument).

The criteria for selecting cases for in-depth interviews were:

- Applied assessment methods in place;
- Data information available;
- High quality NBS (i.e., applying not contested methods);
- Strong focus on adaptation/DRR as main purpose.

Geographic spread was deemed less important.
The interview guide (see Annex 3) was developed with a view to link the results of the case analysis with purposes and approaches of assessing NBS in general (Chapter 2).

3.2 Overview of analysed cases

The thematic coverage of the 38 cases, which replied to the email survey (out of 85 contacted), is shown in Table 4. There appears to be a disproportionate number of cases related to urban and water management NBS; however, as this is consistent with the number of responses and the number of locations in the original 97 cases, this uneven distribution across sectors and thematic areas is not considered problematic in relation to the interpretation of the results or interpreted as an indicator of bias.

Table 4: Responses across sectors and thematic areas.

Sectors and thematic areas	Responses	Sample
Water management	10	**20**
Forests & forestry	4	**8**
Agroforestry	2	**4**
Agriculture	3	**7**
Urban	10	**32**
Coastal	6	**7**
Mountains	3	**7**
Total responses	**38**	**85**

The main climate change risks addressed by the NBS projects are shown in Table 5. The 6 specific risk categories are identified based on the received responses. While some responses did not contain information on the impacts being addressed, others specified more than one. Accordingly, the numbers in Table 5 do not sum to 38. Flood risk management is the dominant risk mitigation theme, representing the main focus in more than 50% of the cases, while drought risk management, heat resilience and erosion are mentioned as a main climate change risks targeted in around 15% of the cases. Wildfire risk management and landslide/avalanche prevention are only mentioned as key in 1 and 2 studies, respectively; this presumably reflects that these two risk types are quite specific for the thematic areas of forestry and mountains, which both are represented by few cases.

Table 5: Climate change risks addressed in cases across thematic areas and sectors.

	Climate change risks							
Sectors and thematic areas	**Flood risk management**	**Drought risk management**	**Wildfire risk management**	**Heat resilience**	**Landslide / avalanche**	**Erosion**	**Other (non-risk) focus***	**No reply**
Urban	7	1		5			2	
Water management	7	3				1		1
Forest and Forestry	1	1	1					2
Agroforestry		1		1				1
Agriculture	2	1						1
Coastal	4					4		1
Mountain					2			1
Total	21	7	1	6	2	5	2	7

Note: Some responses did not contain information on main climate change risks targeted, while others specified more than one. Accordingly, the numbers do not sum to 38.
**Other key focus areas of NBS projects, which go beyond managing climate change related impacts, include, in one case outdoor classroom, awareness/inspiration, citizen involvement and place building. In another case, the focus of the NBS project has been on the establishment of more - and thicker - green roofs as well as reducing energy consumption and protect biodiversity*

The main additional benefits provided by NBS projects are shown in Table 6. Biodiversity and ecosystem services are mentioned as a main additional benefit in more than 50% of the cases, thus by far representing the most frequently cited additional benefit. The replies could indicate a gap in current thinking of considering biodiversity as an additional co-benefit rather than a criterion for implementing and denoting projects NBS in the first place.
Other more frequently mentioned additional benefits include recreation (21%) and water quality (16%). The "Other" category among others includes learning (e.g., outdoor classrooms), awareness raising/citizen involvement and energy savings.

Table 6: Main additional benefits of NBS projects across sectors and thematic areas. Note: Fish & game, groundwater and air pollution were not mentioned among the survey responses.

	Additional NBS benefits							
Sectors and thematic areas	**Carbon sequestration**	**Water quality**	**Land conservation**	**Food production**	**Biodiversity & ecosystem services**	**Recreation**	**Tourism**	**Other**
Urban		1			6	3	1	4
Water management	1	1			8	2	2	1
Forest and Forestry	1	1						1
Agroforestry				1	1			
Agriculture		2		1		1		
Coastal		1	1		3	2	1	
Mountain					2			
Total	2	6	1	2	20	8	4	6

In total, 33 of the 38 cases replying to the email survey stated they have conducted NBS assessments. For quantitative NBS assessments, 33 cases reported having conducted quantitative assessments, 3 cases that no quantitative assessment was made and 1 case did not reply to this question. For qualitative NBS assessments, 30 cases reported they had carried out an assessment while 6 cases stated they had not and 2 cases did not reply to this question. Table 7 outlines how these responses are distributed across sectors and thematic areas. Across all 38 cases, 30 cases conducted both qualitative and quantitative assessments. Thus, both qualitative and quantitative assessments seem to be common for most of the NBS cases that replied to the email survey. This is different from the screening found in the EEA (2021) report that screened 97 cases. The screening, which was only based on information found from the NBS platforms indicated that only about 15% of the 97 cases employ monitoring and/or evaluation. The discrepancy is mainly due to the bias of the email survey replies – cases that did employ assessments are more likely to reply than those that did not. Also, it becomes evident that not all NBS platforms contain sufficient information on the use and results of assessment methods.

Two of the cases report that no assessments had been made due to lack of funding. Considering the low number of cases where assessments have either not been made or where information is missing, it is not possible to identify any trends across sectors and thematic areas. Assessment approaches appear to vary significantly across cases and respondents seem to find it difficult to make a clear distinction between qualitative and quantitative assessment approaches, thus suggesting that the two assessment approaches in reality are often closely intertwined.

Table 7: Use of qualitative and quantitative assessment either before, during or after project implementation.

Sectors and thematic area	Qualitative assessment			Quantitative assessment		
	Yes	No	No info	Yes	No	No info
Urban	9	1		9	1	
Water management	6	3	1	8	1	1
Forest and Forestry	3	1		3	1	
Agroforestry	2			2		
Agriculture	2	1		3		
Coastal	6			6		
Mountain	2		1	2		1
Total	30	6	2	33	3	2

Based on the received responses from the 33 cases stating having carried out NBS assessment, assessments are categorized based on the 4 different types of thematic elements included: social, economic, environmental & technical performance and other. Table 8 provides an overview of the prevalence of these different elements in the cases. Please note that the assessment in Table 8 encompasses both qualitative and quantitative assessment approaches, and that several thematic elements can be used in the same case. Out of the 33 cases having reporting conducting NBS assessments, 29 cases were possible to be categorised into social, economic, environmental and other while 4 cases did not give sufficient information. 11 out of the 29 cases have included both environmental, social and economic elements. The remaining 18 cases conducted 1 or 2 thematic elements. Assessments, which focus on the technical and environmental performance of NBS, appear to be the most popular (25 cases), followed by cases including social (17 cases) and economic thematic elements (14 cases). Of the latter, three cases report that the cost-benefit analyses approach has been used, while an additional 2 studies refer to socio-economic analyses. In 11 cases all 3 thematic elements have been assessed.

Table 8: Overview of the thematic elements employed in the cases reporting to have conducted assessments.

Sector and thematic area	# cases where thematic elements are specified	# cases where thematic elements are NOT specified	Social	Economic	Environmental & technical	Other
Urban	8	1	6	5	7	1
Water management	8	0	5	3	7	
Forestry	2	1			2	
Agroforestry	1	1	1	1	1	
Agriculture	2	1			2	1
Coastal	6	0	4	4	4	
Mountain	2	0	1	1	2	1
Total	*29*	*4*	*17*	*14*	*25*	*3*

Monitoring is one of the purposes of NBS assessments (see Section 2.2.1). A significant share - 30 out of the 38 cases - reported that they either have a monitoring scheme in place or planned (see Table 9).

Table 9: Monitoring initiatives in cases as reported in survey.

Sector and thematic area	Yes	No	No info
Urban	10		
Water management	7	3	
Forestry	3	1	
Agroforestry	2		
Agriculture	3		
Coastal	4	1	1
Mountain	1	1	1
Total	30	6	2

In 24 of the 30 cases reporting to have some kind of monitoring in place or planned, monitoring parameters are specified, while in the remaining 6 no information of the type of monitoring parameters is included. Table 10 provides an overview of the different monitoring parameters used in the studies; note that several parameters can be used in a given case. Flora, fauna and hydrology are the most commonly used monitoring parameters, used in half or more of the cases where monitoring parameters are specified. Water quality and socio-economic parameters are used in about one fourth of the cases.

Table 10: Monitoring parameters used in the case studies.

Sector and thematic area	Flora	Fauna	Sedimen-tation	Water quality	Soil quality	Air quality	Hydro-logy	Morphology	Socio-economic	Other
Urban	3	4	1	2		1	2		5	1
Water management	6	5		3			6	1		2
Forest and Forestry	1	1			1		1			
Agro-forestry	1	1			1				1	
Agriculture				2			2			
Coastal	3	2	2	1			1	3		
Mountain	1				1					1
Total	15	13	3	8	3	1	12	4	6	4

3.3 In depth practical cases

3.3.1 Overview of in-depth cases

Based on the criteria for selecting cases for the in-depth interview, we chose nine cases for in-depth analysis based on interviews with project owners and developers (see detailed case study descriptions in Annex 4). The nine cases represent good examples of how different NBS projects have applied different assessment approaches at various stages of the adaptation planning and implementation cycle (see Figure 5) and of the disaster risk management cycle (see Figure 6). The sectors and thematic areas covered by the nine in-depth cases comprise of three urban cases, two water management cases and one case relating to coastal, agriculture, forestry and mountains respectively.

The three urban cases address challenges relating to pluvial flood protection in Copenhagen, (Denmark), heat resilience through the green roofs programme in Basel (Switzerland) and the Tree Masterplan in Barcelona (Spain). The two water management cases focus on riverine flood protection through the Elbe dyke relocation (Germany) and the Dijle river restoration near Leuven (Belgium). The coastal case focuses on coastal erosion and flood risk management through restoration of former saltworks in the Camargue (France). The agricultural case addresses drought and flood management on agricultural land in Tulltorpsån (Sweden), while the forestry case deals with managing risks of wild fires, flooding and drought in Valencia (Spain) as well as case studies in Germany and Portugal. The mountain case in Engadin region (Switzerland) implemented NBS measures to prevent rock falls, landslides and avalanches. Figure 12 shows a map of the location of the in-depth cases.

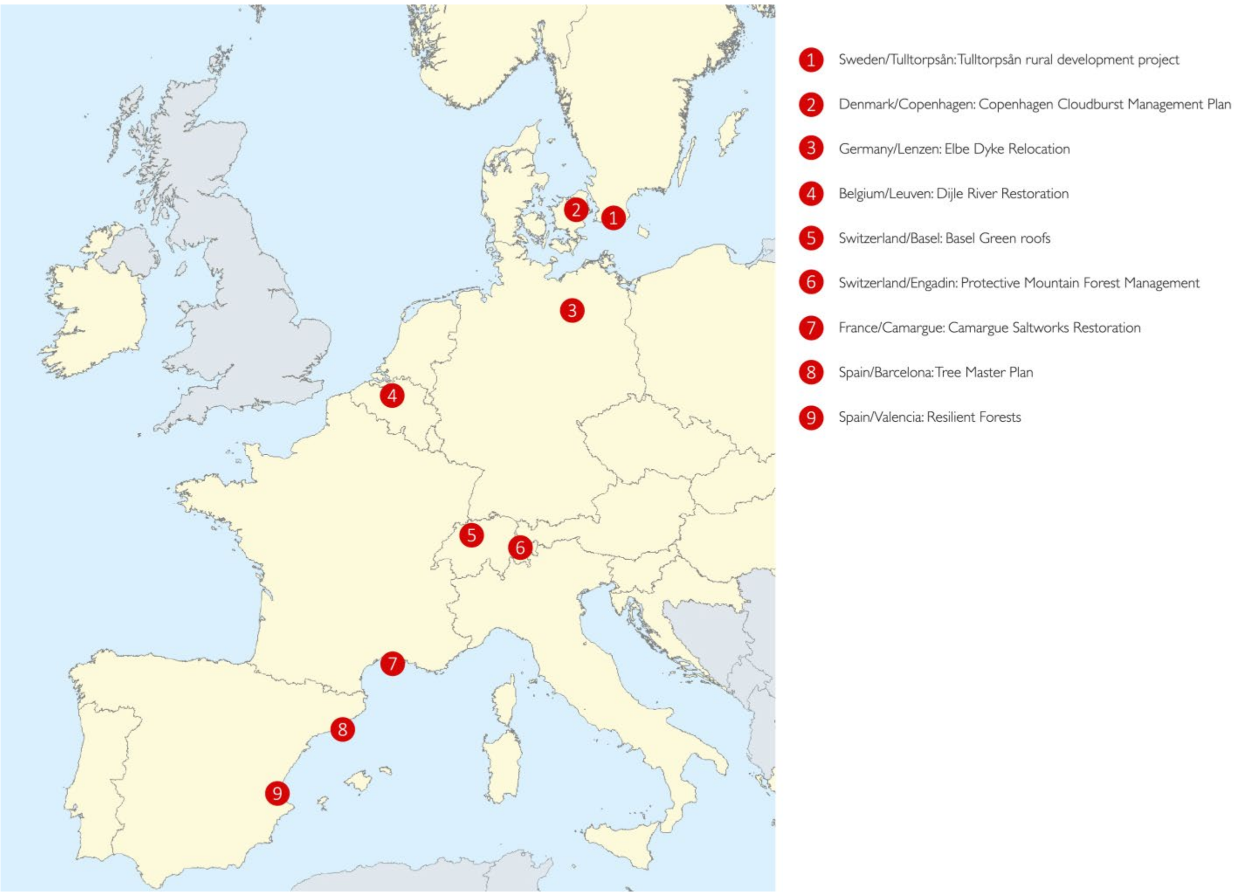


Figure 12: Location and name of in-depth cases.

Assessment approaches applied in the cases vary from ex-ante (including technical feasibility and effectiveness assessments, and cost-benefits analysis) to ex-post assessments (including indicator-based assessments of e.g., tree health, biodiversity and flood occurrence. Methods involve remote sensing, in-situ measurements, assessments of cost-benefits and cost-effectiveness and modelling. Table 11 provides an overview of the cases and assessment approaches applied.

For more information on the case studies, please see Annex 3, which contains the interview guide, and Annex 4 which describes the cases in more detail based on key information collected through the screening of cases for the EEA report (2021), the email survey conducted in April-May 2021 and the interviews carried out from June-August 2021.

Table 11: Overview in-depth cases. Notes: The colouring is made in relation to how the different assessment approaches were implemented during the individual project cycles (green: ex-ante phase; blue: operational phase; red: ex-post phase) and if the assessments had synergistic purposes (black).

Country, region/city	Project name	Sector and thematic area	Climate change risk/ impact addressed	NBS measure	Entry point in CCA/ DRM cycle	Purpose of NBS assessment	Assessment approach	Stakeholder involvement
Sweden, Tulltorpsån	Tullstorpsån rural development project	Agriculture	Drought risk management & flood risk management	Multifunctional wetland, customised drainage system, wetland restoration	CCA Step 3 CCA Step 6	Provide robust evidence base on benefits and trade-offs of choosing between different options Assess technical effectiveness of NBS for risk reduction Assess the costs of implementation and maintenance in support of budget planning For calibration purposes Build understanding and evidence base on the functioning of NBS	Technical feasibility and effectiveness assessment (environmental and hydrological in-situ monitoring and modelling) Cost-benefit assessment	Self-organisation among 500 farmers and villagers
France, Camargue	Camargue Saltworks Restoration	Coastal areas	Erosion & flood risk management	Restoration of coastal habitats	CCA Step 3 CCA Step 6 DRM Prevention & Ongoing maintenance and operation	Provide robust evidence base on benefits and trade-offs of choosing between different options Assess technical effectiveness of NBS for risk reduction and resilience increase Assess the costs of implementation and maintenance in support of budget planning Provide data and messaging for communication on benefits of NBS as adaptation to enhance stakeholder awareness Assess project economic parameters to build the business case for implementation For calibration purposes Build understanding and evidence base on the functioning of NBS Verify design or identify design improvements and possible scale-up Knowledge base for informing future designs, funding and implementation approaches Identify and assess synergistic benefits	Technical feasibility and effectiveness assessment (environmental monitoring, in-situ measurement, remote sensing, modelling) Economic valuation (cost-effectiveness assessment) Indicator-based assessment (monitoring bio-physical and ecological conditions)	Little public engagement to date in project development and implementation, planning to engage
Germany, Portugal and Spain, Valencia	Resilient Forests	Forest and forestry	Wildfire risk management, flood risk management & drought risk management	Sustainable forest management	CCA Step 3 CCA Step 4	Provide robust evidence base on benefits and trade-offs of choosing between different options Assess technical effectiveness of NBS for risk reduction and resilience increase Build understanding and evidence base on the functioning of NBS	Indicator-based assessment (In-situ measurement, modelling, monitoring, Decision Support System tool) Multicriteria analysis (modelling) Cost-benefit analysis	Extensive engagement with public administration & private landowners in project development and pilot phase

Country, region/city	Project name	Sector and thematic area	Climate change risk/ impact addressed	NBS measure	Entry point in CCA/ DRM cycle	Purpose of NBS assessment	Assessment approach	Stakeholder involvement
Switzerland, Engadin region	Protective Mountain Forest Management	Mountains	rockfalls, landslide, avalanches	Protection forest management	DRM: Prevention, ongoing operation and maintenance, and post-disaster evaluation phase	Provide robust evidence base on benefits and trade-offs of choosing between different options Assess technical effectiveness of NBS for risk reduction and resilience increase Assess the costs of implementation and maintenance in support of budget planning Assess project economic parameters to build the business case for implementation For calibration purposes Build understanding and evidence base on the functioning of NBS Assess the effects achieved of NBS on climate impacts / risk reduction	Effectiveness assessment (impacts, risk & state using remote sensing, modelling, in-situ measurements) Cost-benefit assessment (incl. Benefit-cost ratio) Indicator-based assessment	No stakeholder involvement required
Denmark, Copenhagen	Copenhagen Cloudburst Management Plan	Urban	Flood risk management	NBS and surface solutions for water management	CCA Step 3 CCA Step 4 CCA Step 6 DRM: Prevention & Ongoing maintenance and operation	Provide robust evidence base on benefits and trade-offs of choosing between different options Assess technical effectiveness of NBS for risk reduction and resilience increase Assess the costs of implementation and maintenance in support of budget planning Assess project economic parameters to build the business case for implementation Build understanding and evidence base on the functioning of NBS Verify design or identify design improvements and possible scale-up Assess the effects achieved of NBS on climate impacts / risk reduction	Technical feasibility and effectiveness assessment (hydrology modelling) Cost-benefit assessment Economic valuation (cost effectiveness analysis) Indicator-based assessment (environmental impact assessment)	Extensive consultation and co-creation with residents in project development and implementation phase
Spain, Barcelona	Barcelona Tree Master Plan	Urban	Heat resilience	Tree plantation	CCA Step 4 CCA Step 6	Provide data and messaging for communication on benefits of NBS as adaptation to enhance stakeholder awareness For calibration purposes Verify design or identify design improvements and possible scale-up Build understanding and evidence base on the functioning of NBS Assess the effects achieved of NBS on climate impacts / risk reduction Identify and assess synergistic benefits	Indicator-based assessments (impact assessments using in-situ measurements, tree health monitoring, air quality & temperature monitoring, biodiversity monitoring)	Extensive consultation & continuous contact with residents as part of monitoring

Country, region/city	Project name	Sector and thematic area	Climate change risk/ impact addressed	NBS measure	Entry point in CCA/ DRM cycle	Purpose of NBS assessment	Assessment approach	Stakeholder involvement
Switzerland, Basel	Basel Green roofs	Urban	Heat resilience	Green roofs	CCA Step 6	Identify and verify design improvements and possible scale-up Build understanding and evidence base on the functioning of NBS Verify design or identify design improvements and possible scale-up Assess effects achieved of NBS Identify and assess synergistic benefits	Indicator-based assessment (biodiversity monitoring)	Little stakeholder engagement, as limited need
Belgium, Leuven	Dijle River Restoration	Water management	Flood risk management	Restoration of floodplains	CCA Step 3 CCA Step 6	Provide robust evidence base on benefits and trade-offs of choosing between different options Assess technical effectiveness of NBS for risk reduction and resilience increase Build understanding and evidence base on the functioning of NBS Assess the effects achieved of NBS on climate impacts / risk reduction Evaluate the full societal benefit achieved across the full range of benefits, costs and dis-benefits Knowledge base for informing future designs, funding and implementation approaches Identify and assess synergistic benefits	Indicator-based assessment (environmental impact assessment, biodiversity monitoring) Cost-benefit assessment (Social CBA)	Extensive involvement in project development phase - policy representatives, recreationists/tourists, land owners, municipalities
Germany, Lenzen	Elbe Dyke Relocation	Water management	Flood control and flood risk mitigation	dyke relocation to increase water retention area during flood events	CCA Step 3 CCA Step 4 CCA Step 6 DRM: Prevention & Ongoing operation and maintenance	Provide robust evidence base on benefits and trade-offs of choosing between different options Technical effectiveness of NBS for risk reduction and resilience increase Provide data and messaging for communication on benefits of NBS as adaptation to enhance stakeholder awareness Build understanding and evidence base on the functioning of NBS Verify design or identify design improvements and possible scale-up Assess the effect achieved of NBS on the climate impact / risk reduction Knowledge base for informing future designs, funding and implementation approaches Identify and assess synergistic benefits	Technical feasibility and effectiveness assessment (technical & physical impacts, hydrological modelling) Indicator-based assessment (biodiversity monitoring)	Extensive engagement with public administration & private landowners

Note: CCA Step 1: preparing the ground for adaptation; CCA Step 2: Assessing climate change risks and vulnerabilities; CCA Step 3: Identifying adaptation options; CCA Step 4: Assessing adaptation options; CCA Step 5: Implementing adaptation; CCA Step 6: Monitoring and evaluating adaptation.

DRM cycle entry points: i) Planning and implementation of NBS as part of prevention approach; ii) Assessments as part of ongoing maintenance and operation of NBS solutions; iii) Post-disaster evaluation of NBS effectiveness and performance; iv) Post-disaster assessment of the need for NBS improvements or additional NBS.

3.3.2 Lessons learned from in-depth cases

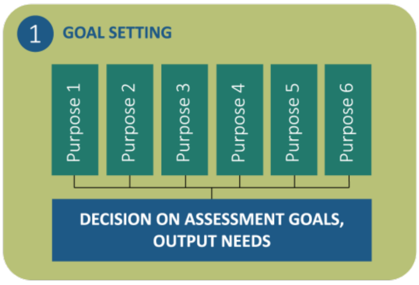
3.3.2.1 Role of Adaptation/DRR in the cases

Adaptation to climate change and/or disaster risk reduction is an inherent element in the implementation of NBS in all the nine investigated cases. Most cases are also developed within a wider perspective to account for restoring habitats, enhancing biodiversity and improving liveability and recreation opportunities. These wider perspectives are often brought in by science partners (e.g., in the Dijle River Restoration, Belgium and Resilient forest, Spain, science partners brought in the wider perspective of accounting for multiple ecosystem services), through policy regulations (e.g., Protective Forest Management, Switzerland, policy regulation required accounting for biodiversity as well), or through the general policy agenda (e.g., Copenhagen Cloudburst Management Plan, Denmark, the municipality had a wish to improve liveability in the city by bringing in more nature). The points below describe how the individual cases approach CCA/DRR within a wider framework.

- In the agricultural case in Sweden (Tulltorpsån), the main adaptation objective is to increase agricultural resilience with regard to drought. This by utilising abandoned industrial ponds as multifunctional wetlands, and customised drainage systems to retain water from the autumn and winter months for use in spring and summer. Expected co-benefits are improved habitats for water fowls and recreation opportunities. The Tulltorpsån case is a recent initiative by local landowners that also initiated the single largest project of its kind in Sweden - a 10-year implementation of NBS along 30 km of the stream in 100 locations, where the main purpose was to improve water quality and biodiversity, but also turned out to be very effective in preventing flooding on agricultural land.
- In the forestry sector, the main purpose of the Resilient Forest case in three countries is both to improve disaster risk and crisis management and adapt to climate change by promoting large-scale forest management practices that increase resilience to wildfires, water scarcity and environmental degradation while supporting biomass production and biodiversity.
- In the mountains of Switzerland, the use of protective forests has shown to reduces disaster risks from rock falls, landslides and avalanches and can under certain circumstances dispense technical protection installations (e.g., nets). Here, also CCA is continuously discussed to improve and refine current forest management strategy to be adaptive to climate change, as well as there is increasing attention to also account for additional forest benefits (e.g., wood production, biodiversity, recreation) in DRM.
- Dyke relocation at the Elbe River at Lenzen, Germany successfully combined the increase of water retention capacity of floodplains for flood protection, while at the same time enhancing habitats for biodiversity. Originally, the main focus of the project was on implementing dyke relocation for habitat restoration and biodiversity conservation. The occurrence of flood events increased awareness of the need for addressing flood mitigation. Hence the project evolved from a biodiversity conservation project to a pilot site for establishing scientific evidence for the contribution of dyke relocation to reducing the peak flow of the river during flood events. Based on the success of this pilot site, dyke relocation has been implemented in several other sites along the river
- In the case of Copenhagen, the cloudburst management plan identifying NBS as a key component and NBS was developed and implemented in the aftermath of an extreme cloudburst event, addressing both DRR and CCA. The plan fed into a wider political agenda to increase green infrastructure and improve liveability in the city.
- In the Dijle valley, the restoration of natural floodplain was originally made with a DRR aim to protect the city of Leuven against flood risk, but CCA has more recently come up with demands to reconsider current water management strategies.
- In Basel, the implementation of green roofs at systematic scale reaching about 40 % of flat roofs aims at countering high temperatures, improving energy efficiency and sequestering carbon while effectively allowing red listed species to inhabit the dense urban area.
- In Barcelona, the ambitious Tree Master Plan seeks i.a., to increase canopy cover to 30% of the surface of the city. Adaptation to high temperatures is but one of several key objectives.

- In the case of the former Camargue saltwork site, restoration of lagoons and marshes re-established the hydrobiological system to both improve biodiversity and implement an adaptive management approach to the rising sea level.

3.3.2.2 Purpose of NBS assessments



As described in Sections 2.2.1.1 and 2.2.1.2, the first Step for a NBS assessment starts with identifying the entry point(s) in the CCA or DRM cycle and this can be further defined and refined into specific purposes of NBS assessments based on the needs of the participating or targeted stakeholders (see Section 2.2.1.3). Table 11 provides an overview of the entry point(s) in the CCA and DRM cycle and the different specific purposes along the project cycle (ex-ante, operational phase and ex-post) of the in-depth cases.

Ex-ante phase

In the ex-ante phase of the project cycle, entry points of NBS assessments include identifying adaptation options (CCA Step 3), assessing adaptation options and planning (CCA Step 4) and implementation of NBS as part of the prevention approach (DRM prevention).

We find that most of the in-depth cases (6 cases) applied assessment approaches in order to identify adaptation options (CCA cycle Step 3). Four cases also defined prevention in the DRM cycle as the entry point. For several projects, there is a natural overlap between CCA and DRR activities (Camargue Saltworks Restoration, Copenhagen Cloudburst Management Plan, and Elbe Dyke Relocation), while for the Protective Mountain Forest Management, DRR is the main purpose, although CCA is continuously discussed in terms of how the management strategy can be improved to be adaptive to climate change.

The in-depth cases include the following specific purposes for ex-ante assessments:

i) **Providing a robust evidence base for informing the project's holders(s) about the benefits and trade-offs of choosing between different options of measures for CCA/DRM** - Tulltorpsån, Camargue Saltworks Restoration, Resilient Forests, Protective Forest Management, Copenhagen Cloudburst Management Plan, Dijle River Restoration, Elbe Dyke Relocation. All of these cases aimed at investigating the impacts and trade-offs of initiating NBS projects whether it is for increasing agricultural resilience, managing flood risks in urban areas, forests and coastal areas, avoiding erosion in mountains and coastal areas or reducing the risk of wildfires and droughts in forested areas. The Basel Green Roof and the Barcelona Tree Master Plan cases were further into the CCA/DRM cycles, focusing on the operational and ex-post assessments.

ii) **Assessing the technical effectiveness of NBS for risk reduction and resilience increase -** Tulltorpsån, Camargue Saltworks Restoration, Resilient Forests, Protective Forest Management, Copenhagen Cloudburst Management Plan, Dijle River Restoration, Elbe Dyke Relocation. All of these cases conducted technical feasibility and effectiveness assessments and/or indicator-based assessments to develop an evidence base for NBS intervention and understanding the impacts and trade-offs. A few cases also carried out economic assessments. The Basel Green Roof and the Barcelona Tree Master Plan cases were further into the CCA/DRM cycles, focusing on the operational and ex-post assessments.

iii) **Understanding the full range of environmental, economic and societal benefits of NBS.** None of the cases conducted a full ex-ante assessment of both environmental, economic and wider societal benefits of NBS implementation. Most cases included ex-ante environmental benefit assessments (Copenhagen Cloudburst Management Plan, Dijle River Restoration, Elbe Dyke Replacement, Protective Mountain Forest Management, Resilient Forests, Tulltorpsån, Camargue Saltworks Restoration), while fewer included also ex-ante assessments of economic benefits (Copenhagen Cloudburst Management Plan, Protective Forest Management, Camargue Saltworks Restoration). Resilient Forests have plans to include economic benefit valuation in the Decision Support Tool in a later stage of the project. None of cases conducted ex-ante assessments of wider societal benefits.

iv) **Assessing the expected costs of implementation and maintenance in support of budget planning.** Several, but not all cases, assessed ex ante the expected costs of implementing and maintaining the NBS options - Tulltorpsån, Copenhagen Cloudburst Management Plan, Protective Mountain Forest Management, Camargue Saltworks Restoration. Assessment of maintenance costs were in most cases not in focus, as the NBS measures to a large extent are unproven by the project holders.

v) **Assessing project economic parameters to build the business case for NBS implementation.** Very few projects have specifically made use of assessments such as cost-effectiveness, net present value and cost-benefit ratios in order to underpin the decision-making process. Copenhagen Cloudburst Management Plan case assessed costs and benefits of combining NBS with traditional grey solutions, estimating the socio-economic net benefits compared to a purely use of grey engineered solutions. The case also conducted cost-effectiveness of different NBS options in 7 catchments covering some 300 projects across the whole city before making the decision to invest substantial amounts of public money over a 20-year period. The Protective Mountain Forest Management case conducted ex-ante cost-benefit ratio analysis for the technical measures planned. The Resilient Forests case plans to include operational costs and benefits into the Decision Support Tool for forest owners. The Camargue Saltworks Restoration case partially assessed economic aspects, mainly focusing on the costs of reconstructing the collapsed seafront dike compared with costs for reinforcing the inner protection and restoring the wetland.

vi) **Provide data and messaging for communication on benefits of NBS as adaptation to enhance stakeholder awareness**. Several of the cases explicitly recognise the value of providing assessment data and insights to a wider audience for scale-up and replication purposes. The Elbe Dyke Relocation case, for instance, represented the first pilot project of its sort in Germany, and the Federal Waterways Engineering and Research Institute had a particular interest in detailed assessment and monitoring of the technical effectiveness to reduce flood risks and to replicate DRR mitigation options in similar sites, while the Federal Agency for Nature Conservation had a particular interest in assessing ex-ante the potential for biodiversity improvements and monitoring the development in the area for further knowledge build-up in similar projects. Today, there are about 10 similar projects in implementation stage and more projects are in planning across Germany as a result of the robust and positive assessments. The Barcelona Tree Master Plan conducts a finely meshed, thorough and systematic monitoring of all trees in the city which is used i.a., to keep track of progress toward the target of the Tree Master Plan: to reach 30% canopy cover by 2037; to reduce the presence of any given tree species to maximum 15% to increase climate resilience and to ensure that all primary school children appreciate and can identify trees in the neighbourhood. The Camargue Saltworks Restoration case uses the evidence base to also share experiences with the wider public, academia and practitioners through videos, workshops, scientific congresses, brochures and fact sheets for possible replication and scale-up.

vii) **Assessments of NBS potential for carbon or biodiversity credit/offset or compensation scheme** and

viii) **Assessments to build a financial case for attracting sustainable private sector finance**. None of the nine cases had a specific purpose to obtain credits or to attract private sector finance.

Operational phase

In the operational phase of the project cycle, entry points of NBS assessments include implementing adaptation options (CCA Step 5), monitoring and evaluation (CCA Step 6) and ongoing operation and maintenance phases in DRM cycle.
We find that about half of the in-depth cases (five cases) applied assessment approaches during the implementation of adaptation (CCA Step 5) and conducted monitoring and evaluation in the operational phase (CCA cycle Step 6). Four cases also carried out assessments relating to the DRM entry point ongoing maintenance and operation of NBS solutions. As in the ex-ante phase, several projects have a natural overlap between CCA and DRR activities.

The in-depth cases include the following specific purposes for operational phase assessments:
i) **Calibration purposes** - Protective Forest Management, Camargue Saltworks Restoration, Tulltorpsån and Barcelona Tree Master Plan use assessments for calibration purposes to continuously improve effectiveness and resilience of the NBS interventions.

ii) **Building understanding and evidence base on the functioning of NBS**. All cases aim to build understanding and evidence base on the functioning of NBS, using different assessment approaches according to the needs of the stakeholders and themselves as project-holders (See Section on drivers of assessment).

iii) **Verifying the design or identifying design improvements and possible scale-up.** The Basel Green Roofs case has over a long time period developed and refined a monitoring design for assessing how different types, sizes and locations of green roofs enhance biodiversity and has developed guidance for other stakeholders across Europe to replicate a robust monitoring approach. Barcelona Tree Master Plan case systematically uses assessment outputs to continuously evaluate and update urban tree planting (choice of species, location and infrastructure) to ensure a resilient and safe tree environment. Copenhagen Cloudburst Management Plan uses technical and cost-effectiveness assessments at local scale to verify the choice and dimensioning of hybrid NBS solutions and updates the evaluations every 4-years with the latest scenarios, the Camargue Saltworks Restoration case uses the assessment output to continuously update the management place of the site and the Elbe Dyke Restoration case uses the ex-ante modelling combined with ex-post monitoring of flood risk reduction impacts to draw lessons for replication elsewhere.

iv) **Assessing and reporting the expenditures and benefits ratios, including for supporting maintenance case budgeting.** None of the cases explicitly assess and report expenditures and benefit ratios including to support maintenance case budgeting. However, aspects of this are found in the ex-ante phase of the cases such as the Protective Mountain Forest case, estimating benefit-cost ratios to select the right measures, the Copenhagen Cloudburst Management Plan case, calculating cost-effectiveness of different solutions to select the optimal measures at local scale and the Barcelona Tree Master Plan case, where the systematic monitoring of urban trees is used internally in the organisation and towards management to ensure that health and safety in the city is secured even with currently 25% canopy cover.

v) **Assessment of the asset value of NBS for inclusion in balance sheets**. None of the cases have the purpose to include the asset value of NBS in balance sheets.

Ex-post phase

In the ex-post phase of NBS projects, entry points of NBS assessments include monitoring and evaluating adaptation options (CCA Step 6), and post-disaster evaluation of NBS performance and effectiveness and post-disaster assessment of the need for NBS improvements or additional NBS phases in DRM cycle.
We find that four of the in-depth cases applied assessment approaches conducted monitoring and evaluation in the ex-post phase (CCA cycle Step 6) (Barcelona Tree Master Plan, Elbe Dyke Relocation,

Camargue Saltworks Restoration, Basel Green Roofs, Dijle River Restoration). Two cases (Protective Mountain Forest Management and Elbe Dyke Relocation) also carried out assessments relating to the DRM entry point post-disaster evaluation of NBS effectiveness and performance. As in the operation and ex-ante phases, several projects have a natural overlap between CCA and DRR activities.

The in-depth cases include the following specific purposes for ex-post assessments:

i) **Assessing the effect achieved.** Most cases aim to assess the effects achieved of the NBS. The Protective Mountain Forest case makes use of extensive monitoring and example plots to evaluate in practice the impact of erosion control interventions. The Copenhagen Cloudburst Management Plan case is developing and piloting automated monitoring of the local NBS measures in the realisation that with 300 projects when the plan is fully implemented, a manual and frequent monitoring is not feasible. The Dijle River Restoration case i.a., conducted ex-post social Cost Benefit Assessment and the Elbe Dyke Relocation case monitored in detail the effectiveness of the dyke relocation during subsequent flood events and identified impacts of the project in terms of economic impacts, human/social/cultural impacts and environmental impacts. The Barcelona Tree Master Plan case continuously monitors, evaluates impacts of tree interventions and adapts the management plan to ensure robust and safe NBS. Assessments are also made by the municipality on the impacts on air pollution and air temperature. The Basel Green Roof case analyses and publishes results from the monitoring of biodiversity.

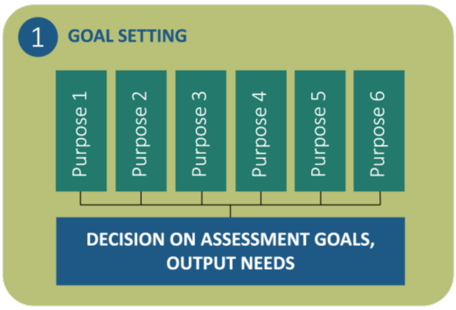
Not all projects focus on the climate impact/risk reduction, but on synergistic purposes and benefits of NBS assessments. This is the case, for instance, with the Basel Green Roof case, that has carried out biodiversity in-situ monitoring on 25 green roofs since 2013.

ii) **Assessing the return on investment made.** None of the cases aim to assess the return on investment made, although this would be possible in several of the cases.

iii) **Evaluating the full societal benefit achieved across the full range of benefits, costs and dis-benefits of NBS.** Only the Dijle River Restoration case evaluated the full societal benefits ex-post through a social cost-benefit analysis. The Tulltorpsån generation 1.0 case conducted ex-post evaluation of benefits generated from ecosystem services improved through the NBS measures, while the Tulltorpsån generation 2.0 case has not yet reached this point. However, several of the cases aim to or would like to include evaluations of full societal benefits. This includes the Copenhagen Cloudburst Management Plan, the Barcelona Tree Master Plan and the Resilient Forest. Other projects have identified, but not assessed societal benefits including the Elbe Dyke Relocation and the Camargue Saltworks Restoration cases.

iv) **Knowledge base for informing future designs, funding and implementation approaches for NBS as adaptation/DRM measures.** Three cases specifically aim to build a knowledge base to inform future projects. This includes the Camargue Saltworks Restoration case, where the assessment outputs can be capitalised upon in other similar areas; the Elbe Dyke Relocation case, where the project holders were interested in gaining experience for replication and scale-up; and the Dijle River Restoration case, where the assessment outputs were used to raise awareness and demonstrate the potential for multiple benefits and cost savings of employing NBS compared to grey options. Other projects may not have had the original aim to inform future designs and implementation approaches elsewhere, but the quality and success of the NBS interventions combined with the development and choice of assessments approaches have meant they become knowledge hubs for other similar projects. This is the case for the Copenhagen Cloudburst Management Plan case, where the Ministry of Environment has developed a national requirement to municipalities on conducting cost-effectiveness assessments in adaptation projects, based on the approach developed by the Municipality of Copenhagen. Also in the case of Barcelona Tree Master Plan, the monitoring and evaluation design developed for tree management and the knowledge accumulated in the Department is frequently demanded by cities in similar climatic zones.

3.3.2.3 Synergistic purposes and benefits of NBS assessments



As described in Section 2.2.1.4, expanding the purpose of NBS assessments outside the CCA/DRM realm to include other synergistic purposes will increase the resource-effectiveness of an NBS assessment. Such synergistic purposes may include supporting biodiversity and other environmental management policies, integrating climate change mitigation, providing the data basis for carbon or biodiversity compensation schemes, improving understanding of benefits related to physical and mental health and including the considerations of social benefits and just resilience (See Section 2.2.1.4).

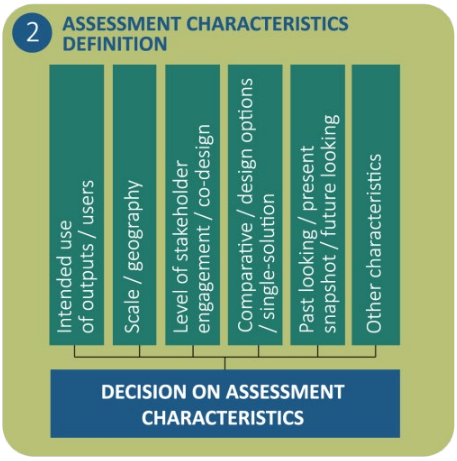
In terms of **biodiversity**, the case of Elbe Dyke Relocation illustrates how an assessment of relocating a dyke for biodiversity purposes developed into a CCA/DRR project after a major flood event. Today, the case assessments conducted cover both flood risk mitigation and biodiversity purposes and are used for replication in similar locations across Germany. The Basel Green Roof case was originally motivated by energy savings although other benefits e.g., storm water management was also recognised. Today, 40% of flat roofs in Basel are green roofs and a requirement for green roof on new or renovated flat roofs is in place in the building code in the canton. The municipality has previously conducted assessments on the potential for energy savings, but not in terms of storm water runoff. Long-term in-situ biodiversity monitoring on 25 roofs since 2013 every two-weeks in the growing season reveal a fair share of red-listed species present. It is expected that once the long-term monitoring data has been analysed in full, there will be sufficient proof of the benefit of green roofs for biodiversity such that green roofs will become integrated in the national building code for flat buildings. The Camargue Saltworks Restoration case has monitored environmental impacts, including impacts of biodiversity during all phases of the project, covering changes in water flow, water level, salinity, salt marsh accretion and extension and distribution of aquatic plants, benthic macroinvertebrates, fish and water birds. The Protective Mountain Forest Management case, originally focus on DRR, but increasing attention is now also to account for additional benefits including wood production, biodiversity and recreation, and to integrate these into the overall assessment.

In terms of other **environmental management policies**, the Tulltorpsån case originally developed in 2014 from a concern of water quality and nutrient loading to the Baltic Sea. With the implementation of some 100 NBS projects along the 30 km water course, project holders realised, thanks to the evidence from the assessments carried out during and ex-post, the potential for flood and drought mitigation. The Tulltorpsån generation 2.0 case is now purely focusing on mitigating flood and drought. The Dijle River Restoration case conducted an ex-post social cost benefit assessment looking at multiple benefits such as flood control, water quality, carbon sequestration, biodiversity, air quality, recreation and landscape experience. The Copenhagen Cloudburst Management Plan case is carrying out environmental impact assessments during the operational phase especially in relation to impacts of the NBS and other surface solutions on water quality under the EC Water Framework Directive.

In terms of **physical and mental health and social benefits** many of the cases recognise the importance of the NBS projects on direct human wellbeing including recreational activities emerging in the Camargue Saltworks Restoration case, in the Dijle River Restoration case, in the Tulltorpsån generation 1.0 case. Improved daily living qualities are well recognised, but not assessed in the case of Copenhagen Cloudburst Management Plan case and the Barcelona Tree Master Plan case. In the Copenhagen Cloudburst Management Plan case, several of the NBs projects are integrated with city renewal plans with a strong component of local ownership, fostering social justice and social cohesion.

Potential for **job creation** is included in the Decision Support Tool of the Resilient Forest case, and the municipality of Copenhagen also aims for export of new methods and experiences to be part of the Cloudburst Plan. Several international collaborations are in place with cities such as New York, Buenos Aires and Beijing, where Copenhagen provides planning and consultancy services.

3.3.2.4 How were the assessments intended to be used?

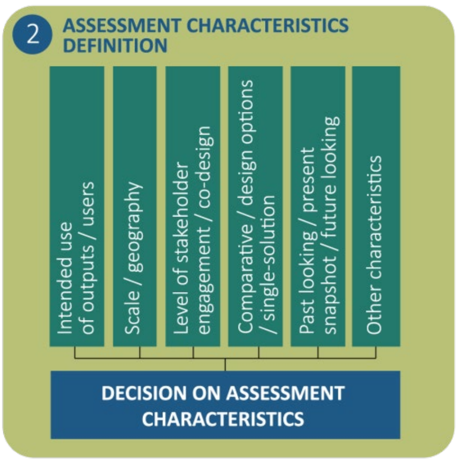


As part of purposes and output needs, understanding how the assessments are intended to be used can help shape the definition of which type of assessments, their characteristics and elements and which approaches are relevant. As the cases clearly indicate, assessments can be used for a variety of purposes. City authorities among investigated case studies (i.e., Copenhagen and Barcelona) used assessments to keep higher management continuously informed, keep track of progress on long-term strategic management plan and in a continuous risk management effort, or to take strategic long-term decisions that are optimal and cost-effective and to help determine the most optimal adaptation options. Likewise, agencies responsible for mountain forest management and DRR in Switzerland use NBS assessments to support daily forest management, monitoring, re-defining regional and national strategies, in relation to rockfalls, landslide and avalanche control. And in the Elbe Dyke relocation case, the federal agencies used the assessments to build evidence on effectiveness of flood risk mitigation and impacts on biodiversity in order to replicate this in similar contexts across Germany.

Farmers in the case of Tulltorpsån, who founded an economic association to run the day-to-day NBS activities, wished to understand the effectiveness of NBS options in quantitative terms as they have given up a part of their farm land to NBS and need to know 'is it worthwhile?'. The farmers also wanted to understand the role that different methods may have on assessment results, while landowners of the Camargue Saltwork Restoration case use assessments to inform adaptive management during and after project implementation and to enable transfer of experiences to similar locations.

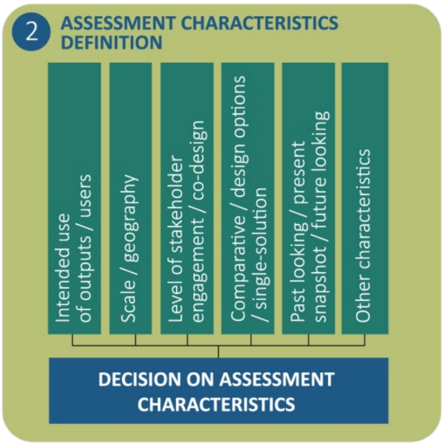
Research institutions involved in the cases aimed to advance resilient management practices among land owners beyond the specific NBS case. For instance, the Resilient Forest case developed a Decision Support Tool, introducing climate change (and their potential impacts on the forest) and Sustainable Forest Management to forest managers and forest owners in Germany, Portugal and Spain. In the Basel Green Roof case, the monitoring was conducted by a university, aiming at informing planners and policymakers at local, regional and national level of the impacts of NBS in relation to biodiversity on green roofs. In the Dijle River Restoration case, the environmental impact assessment and comparative social cost-benefit analysis of the Dijle floodplain restoration assessment aimed to showcase how nature and water management can go together, supporting arguments in favour of NBS within national agencies.

3.3.2.5 Scale and geographical context



Scale and geographic context are key aspects to consider in defining the characteristics of assessments. Results of the assessment may well depend on the scale. Assessments identified in the case studies range from plot scale to catchment scale, regional and national scale. For example, the Decision Support Tool developed in the Resilient Forest case is based on regular site visits and stakeholder consultations in the three different counties, which helped to clarify the needs for adaptation and DRR within the specific various local contexts. Assessments carried out in the Protective Mountain Forest case are partly done on plot scale (baseline assessment, in-situ measurements) as well as feed into national-scale assessment (national hazard map). Technical/physical NBS monitoring in the case of the Barcelona Tree Master Plan accounts for the whole city. Similarly, the physical, technical and economic assessments in the Copenhagen Cloudburst Management Plan case cover the whole city area, but has more detailed assessment at catchment scale and very local and specific assessments at individual NBS implementation level. The Dijle River Restoration case is delineated by the flood plain area immediately in the backyard of the city of Leuven while the Elbe Dyke Relocation case was defined originally by the nature restoration project area. The Tulltorpsån case was originally an idea with few landowners and with limited impact, which grew over a decade to cover 30 km of the water course with today about 100 local NBS projects that in combination improved both water quality and flood risk mitigation, making it the largest project of its kind in Sweden. Defining characteristics of assessments therefore need to take into account both the intended purpose and the dynamic context in which NBS projects often evolve.

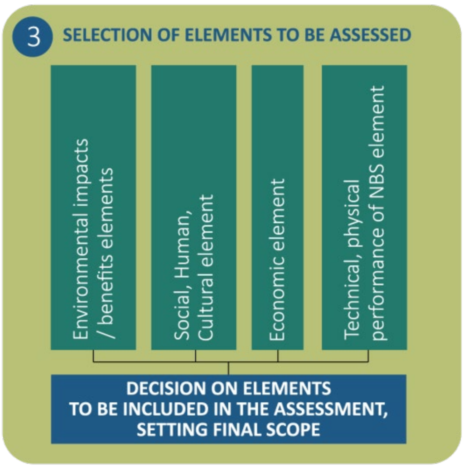
3.3.2.6 Stakeholder involvement and social vulnerability



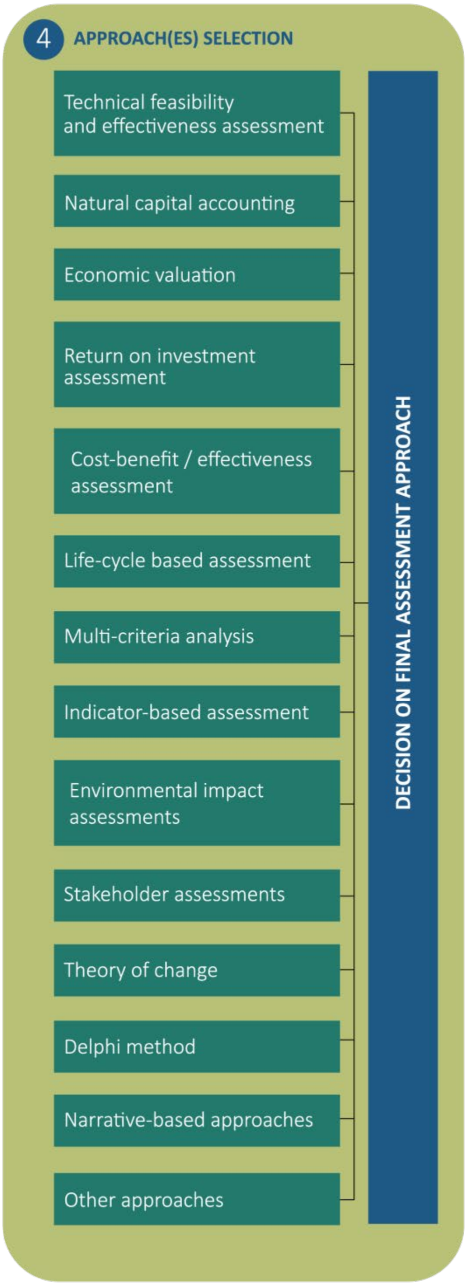
One of the aspects to consider when defining the characteristics of assessments is the extent and role of stakeholder involvement. The involvement of stakeholders in the in-depth cases range from no or only partial involvement, to extensive consultation of and co-creation with local stakeholders (e.g., residents) through to stakeholders themselves self-organising and forming an economic association to carry out large-scale NBS over more than a decade. In the Copenhagen Cloudburst Management Plan case, extensive consultations and citizen meetings were held on the strategic plan for the Cloudburst Management Plan and dedicated co-creation processes continues to be run with residents in neighbourhoods where NBS is about to be implemented, creating a strong sense of ownership and care. Several of the 300 NBS projects in Copenhagen are part of neighbourhood renewal plans, addressing social justice and cohesion. In Barcelona Tree Master Plan case, the development of the Tree Master Plan entailed an extensive consultation of stakeholders, especially with all types of stakeholders, where conflicts could be expected. Barcelona also makes extensive use of narrative-based storylines to improve acceptance and appreciation of biodiversity and understanding the life that comes with a dense population of urban trees.

In the resilient forest case in Germany, Spain and Portugal, stakeholder involvement was instrumental in the development of the Decision Support Tool and in the Dijle floodplain restoration project in Belgium, stakeholder involvement in the form of a steering committee, played an important role to discuss, refine and validate assessment results. The most extensive form of stakeholder involvement was found in the Tulltorpsån case in Sweden. Here 90 farmers and more than 400 villagers and local residents are part of the self-organised economic association that employs a professional project manager and a bookkeeper to obtain external funding to realise more than 100 projects along the river since 2014. Members of the association meet twice yearly to discuss projects, issues and progress in addition to newsletters and hosting numerous visitors from other regions.

3.3.2.7 Type of assessment approaches selected



All in-depth cases conducted technical and/or physical assessments of NBS prior to implementation and most have an assessment during the operational phase and ex-post to better understand the performance of NBS. Technical/physical impact assessments in the in-depth cases include both ex-ante, during the operational phase and ex-post evaluations using both advanced modelling approaches and practical measurements and registrations. Examples include the use of modelling, in-situ measurements, remote sensing and hydrological modelling in the case of the Camargue Saltworks Restoration case and the Protective Mountain Forest Management case; and the use of fine-resolution hydrological modelling of flood risks in the Copenhagen Cloudburst Management Plan case.



An example of a tool for decision support based on physical impact assessment is found in the Resilient Forest case, where in-situ measurements, modelling and stakeholder involvement are key methods within the tool. Fewer cases, however, conduct economic assessments of NBS performance or carry out only partial economic assessments. Two comprehensive socio-economic assessments have been carried out in relation to flood protection. The Copenhagen Cloudburst Management Plan case made an ex-ante socio-economic assessment of the optimal flood protection level for the whole city (Københavns Kommune, 2014), followed by local level cost-effectiveness assessments, comparing NBS with grey and hybrid solutions. The Dijle River Restoration case made an ex-post comparative social cost-benefit analysis to evaluate the implemented NBS. On the benefit valuation of NBS, the Tulltorpsån case carried out an ex-post economic valuation of seven ecosystem services enhanced through the 100 NBS projects implemented along the Tulltorpsån river, including biodiversity, water regulation, nutrient retention, recreation, and tourism and using non-market and market-based methods. In the case of Protective Mountain Forest Management and in the case of Camargue Saltworks Restoration, partial economic assessments have been carried out ex-ante and/or ex-post on cost-evaluations to identify the best adaptation option (including grey alternatives). For the Camargue Saltworks Restoration case, economic aspects were assessed ex-ante qualitatively and ex-post quantitatively. The Barcelona Tree Master Plan and the Resilient Forests cases both plan or would like to include cost-benefit analyses of NBS in future assessments.

Monitoring during the operational and ex-post phase played a key role in several of the cases. For the Barcelona Tree Master Plan case, a systematic and 2-year cycle of qualitative and quantitative monitoring of individual tree health combined with a complaint registration system from residents about nuisances ensures that Barcelona can safely maintain a 25% canopy cover in a dense urban area and continue to increase the extent of urban trees up to 30% and avoid accidents. For Tulltorpsån, a continued monitoring of e.g., peak flow at the mouth of the river documented the impact of the circa 100 NBS project established along the 30km Tulltorpsån river. Peak flow as a result has reduced from $12m^3$/sec to $5m^3$/sec in winter months, leading to an absence of flooding. Also the Elbe Dyke Relocation case continues to monitor both flood risk effectiveness and biodiversity development on the site. In the Protective Mountain Forest Management case, monitoring is a key method of ongoing maintenance and operations with a cycle of systematic indicator-based monitoring of forests every 5 years, post-disaster evaluation of NBS effectiveness and post-disaster assessment of needs of NBS improvement. In Basel Green Roofs case, ex-post indicator-based monitoring has taken place twice monthly in the growing season for more than 10 years, registering development of biodiversity on green roofs.

One case – Barcelona Tree Master Plan – explicitly makes use of narrative-based storylines to improve acceptance and appreciation of biodiversity and increase residents' understanding of the type of life that comes with a dense population of urban trees.

3.3.2.8 Funding & Budget for assessments of NBS

DATA AND RESOURCE CONSIDERATIONS ARE RELEVANT FOR ALL STEPS

Assessments of NBS are generally funded by either the project holder itself via the local authority budget (e.g., Barcelona Tree Master Plan and the Copenhagen Cloudburst Management plan), by national funding bodies especially interested in understanding the effectiveness of the projects (e.g., the National Environmental Agency in the case of Basel Green Roofs and the multiple federal and regional funding streams to the Elbe Dyke Relocation case) or by funding bodies at national or EU level of the projects, requiring assessments as part of the grant (e.g., the Camargue Salt Works Restoration and the Dijle River Restoration). Funding bodies include LIFE+, Interreg, Rural Development Programme, national, regional and local funding. A few exceptions include the Resilient Forest case with 40 % funding coming from private sources and the Tulltorpsån generation 2.0 case, which is based on autonomous adaptation of an individual large-scale farmer, securing part funding from NEFCO and WWF for the adjustable drainage system and with the plans to seek funding from the up-coming Rural Development Programme, when it allows applications on water storage for countering droughts. Many of the projects have a diversified portfolio of funding sources. Two cases - Tulltorpsån and Elbe Dyke Relocation – created associations specifically with the aim of being able to obtain funding from different sources, including funding for assessments of NBS.

In several of the cases, NBS assessments are considered extremely important. In the case of Copenhagen Cloudburst Management Plan, the cost-effectiveness and socio-economic assessments primarily serve to avoid maladaptation and poor use of public finance. With a total implementation budget of up to 1.8 billion EUR (2011 prices), a poorly made or a lack of assessment can risk leading to significant mis-investments. In the case of Tulltorpsån, the farmers behind the project place a high importance in understanding the effectiveness of the measures taken on their land. The benefits of the NBS projects need to outweigh the costs of giving up part of their land for remeandering and construction of wetlands. Also, in the case of Tulltorpsån, the success of the project led the national Agency for Sea and Water to fund an extensive evaluation of the project to better understand underlying success factors. In the case of Barcelona Tree Master Plan, the very ambitious agenda of working with a high canopy cover in a dense urban environment requires the city to run a systematic and constant monitoring and registration of incidents linked to tree debris, potentially leading to health and safety risks. In the mountain case in Switzerland, regular assessments (e.g., assessing performance NBS) are required by national legislation.

One of the cases – Basel Green Roof – does not anymore rely on public funding for the implementation of the NBS. Starting out as a voluntary subsidy to homeowners in 1996 from an energy savings fund, green roofs for flat buildings are now part of the building code in Basel canton. The first biodiversity monitoring was also paid from the energy savings fund and is now covered by the Federal Ministry of Environment.

3.3.2.9 Drivers of assessment

Drivers of conducting NBS assessments in the projects include specific requirements from funding bodies, policy or/and demands and questions from the field.
In the case of the Basel Green Roof case, the funding aimed specifically at carrying out monitoring of biodiversity. Similarly, in the case of Camargue Saltworks Restoration, performing an assessment was required by the used funding mechanisms. National guidelines for risk management were one of the key reasons for carrying out an NBS assessment in the Protective Forest Management case. Demands and questions from the field to ascertain the options and effectiveness of NBS led to the development of a decision support tool in the case of Resilient Forests, where forest managers needed alternatives to expensive forest management practices. This was also found in the case of Tulltorpsån, where farmers wanted to understand and to follow over time the impacts and benefits of giving up their land for river restoration and wetland construction. Interestingly, farmers in the Tulltorpsån case also asked for evaluating the different assessment methods to ensure robust evaluation approaches. For the untested customised drainage system that the Tulltorpsån plan to implement in order to counter drought events in agriculture, the funding organisation NEFCO required a two-Step approach to the project, starting with the pre-feasibility study before deciding on moving further on to the detailed technical study and implementation.

A number of cases have implemented NBS assessments as part of local and national policy agendas: In the case of Copenhagen Cloudburst Management Plan, the extensive body of assessments were motivated by the need to avoid misinvestment and ensure optimal flood protection for the whole city while ensuring added values and synergies with wider agendas of neighbourhood renewal and increasing liveability. In the case of Barcelona Tree Master Plan, the systematic monitoring of tree health and safety to prevent any health hazards for residents is considered the prerequisite for having a very dense canopy cover in the dense urban area. In the case of the Dijle river restoration, the water management agency requested an assessment comparing grey and NBS options to showcase a good example of NBS. In the case of the Elbe Dyke Relocation, the size and importance of the project as the first of its kind in Germany motivated the federal Agency for Hydraulic Construction to conduct detailed assessments and monitoring of the effects of dyke relocation on flood reduction.

3.3.2.10 Barriers & success factors for NBS

Barriers

Working with NBS in practice necessitates interdisciplinary approaches and collaborations. However, working in multi-disciplinary teams requires both time and dedicated processes to understand each other and integrate different views. Projects have also faced methodological challenges e.g., due to lack of data.

Initial scepticism among stakeholders (Tulltorpsån case) or a lack of local acceptance or even local opposition (Camargue Saltwork Restoration case) have proven to be barriers to reckon with. The projects demonstrate, however, that by informing, involving and especially demonstrating the robustness of NBS in solving challenges, initial local resistance can be turned around.

A lack of integration across policy areas can lead to unintended consequences, for instance between urban cloudburst management using NBS and the EU Water Framework Directive (Copenhagen Cloudburst Management Plan case). NBS for cloudburst management retains water that is ultimately led to surface water bodies without going through a waste water treatment plant. The Water Framework Directive however requires security that water quality is not deteriorated by introducing NBS, while in the absence of acting, the city would not be subject to the same requirements. Also retroactively introduced national regulations on NBS assessment for climate adaptation in Denmark has shown to delay and introduce uncertainty in planning and implementation. Furthermore, the implementation of NBS measures and assessing their effectiveness can require the participation and collaboration of multiple actors including land users, decision makers in public administration and citizens. Building relationships and facilitating a fruitful participatory process can be key for enhancing the chances of success, but it can take several years (e.g., Elbe Dyke Relocation).

For NBS projects that operate over long time periods and that are dependent on external funding (e.g., Tulltorpsån case), the excessive time and efforts spent on securing external funding and reporting to funding bodies, especially when multiple funding bodies are involved, can be experienced as a nuisance. Also, inflexible funding rules that do not allow novel types of NBS have been shown to delay implementation. An example is the Tulltorpsån case, where the status of the socio-economic association that farmers had created in order to apply for external funding was not eligible to apply for funding. However, the promising approach of Tulltorpsån led the funding agency to alter rules to allow considering applications from that type of applicant.

Total economic value of NBS (e.g., including also non-market use and non-use benefits of NBS) is rarely quantified in assessments of NBS, even if case owners find this important and relevant. In the case of Copenhagen Cloudburst Management, the socio-economic assessment excluded non-market values of NBS despite these values being key aspects that citizens and politicians demand (e.g., increasing urban green areas, improve biodiversity and recreation opportunities). This type of values was excluded to avoid potential criticism, based on the explicit exclusion of non-market benefit valuation in national guidance of socio-economic assessments of public investments made by the Danish Ministry of Finance. The lack of assessing the total economic value of NBS may bias conclusions and remove attention to maximising co-benefits of NBS implementation.

Budgets appear in most of the nine cases not to be a major barrier or have been solved over time. In the Barcelona Tree Master Plan case, however, the allocated budgets fail to follow the level of ambitions set out in politically agreed strategies.

Successes

Stakeholder involvement have in several of the nine cases shown to play an important role for a robust NBS assessment. In the Resilient Forest case, the involvement of stakeholders brought up new relevant topics (e.g., biodiversity) that were not foreseen in the project planning. In Tulltorpsån case, the self-organisation of stakeholders and direct interest of land owners in understanding the effectiveness and impact of NBS on their land has spurred an impressive number of systematic assessments since the project start in 2014.

Demonstrating the insurance value of NBS through detailed technical/physical and economic assessments is considered to be a competition factor for the city of Copenhagen. The implementation of the cloudburst plan on neighbourhood level protects households against a 1:100 extreme rain event. This collective investment, paid by residents via the utility bills and municipal taxes represents an insurance value that could be used to decrease individual insurance costs of households, or at a more generic level to avoid an increase in the re-insurance costs for insurance companies. This also stabilizes property values and improves opportunities for investing in Copenhagen, as risks from climate change impacts are under control.

Assessments that are policy-driven with a clear mandate and objectives have the clear advantage that it's not necessary to convince people about the virtues of carrying out evaluations (e.g., Dijle River Restoration case). Also, adverse events causing significant damages and general recognition of climate hazards have shown to be conducive for embarking on ex-ante assessments (Elbe Dyke Relocation case, Copenhagen

Cloudburst Management Plan case), although adverse events can hardly be coined a success factor by and of itself.
Systematic monitoring of NBS has proven to significantly reduce health and safety risks in the case of urban trees in Barcelona. Politicians have come to recognise the value and importance of systematic monitoring through the absence of serious accidents from falling branches and trees, which also makes it possible to implement the ambitious strategy to further increase canopy cover in Barcelona. Without such continuous risk assessments based on monitoring, it would not be possible to avoid serious accidents, and politicians would not be comfortable pushing for urban tree expansion.
Sufficient data availability for conducting assessments is an important prerequisite for successful evaluations. The extensive amount of data on buildings, infrastructure, hydrology and socio-economic data on residents in Copenhagen made it possible to carry out a city-wide assessment on flood risks, cost-effectiveness of NBS measures and cost-benefit assessment of different flood risk levels.

Ex-post assessments in projects where NBS has clearly made a rapid and positive impact (e.g., on flood protection and biodiversity) have in several cases been used to showcase the potential for NBS to other regions (e.g., Dijle River Restoration, Elbe Dyke Relocation, Tulltorpsån). Planning, assessments and implementation of NBS at large-scale in Copenhagen has spurred international interest and collaborations with cities like New York Buenos Aires and Beijing, where the municipality of Copenhagen provides planning and consultancy services and welcomes many delegations since 2012 to learn from the experiences of NBS implementation on the ground. Similarly, the Elbe Dyke Relocation case served as a pilot site for a NBS measure for flood mitigation attracting national and international experts and decision makers interested in replicating a similar measure elsewhere. For enhancing the acceptance of and local support for NBS measures it can be critical to assess also the multiple benefits that NBS measures provide in addition to their benefits for adaptation and disaster risk management. Such an assessment can address economic benefits including the creation of jobs (e.g. the area of the Elbe Dyke Relocation enhanced the attractiveness of the landscape and increased the local tourism sector) but also intrinsic values related to scenic beauty and sense of place.

4 Conclusions

Nature-based solutions play an important and increasing role in both adaptation and disaster risk management. This is also recognized within several global and European agreements and policies (e.g., UN's SFDRR, EU Green Deal, the EU Adaptation Strategy) which embed NBS as a means to address CCA and DRR as well as other societal challenges (e.g., biodiversity loss, climate mitigation). This calls for fit-for-purpose assessments, which critically assess the suitability of NBS for addressing climate change and other hazard impacts and monitor the success of their implementation, to inform (future) policies and actions, as well as evaluate implemented policies.
There are several NBS assessment frameworks suggested (see e.g., EC 2021). However, navigating the complexity of design options and possible methods for NBS assessments remains a challenge. Here, we developed a step-wise framework for designing user-oriented NBS assessments, building on key success factors and limitations identified in the literature. The framework consists of four recommended steps: 1) clear **identification of the purpose and specific goal(s)** and outputs that address stakeholder needs, 2) **defining assessment characteristics** balancing the purpose and output needs with resource considerations, 3) **selection of elements** to be included in the assessment, such as technical, environmental, social or/and economic and finally, 4) **choice of the assessment approach or a mix of approaches** (combined, embedded or used in sequence). Each NBS assessment will have its unique individual pattern addressing its particular context and purpose. In this study, we used real-life NBS cases implemented across the EU to illustrate and discuss a range of different NBS assessments approaches in the context of CCA and DRR (see Annex 1 for an overview), and reflect on the key elements of the suggested framework.

Strategic planning of NBS assessments for CCA and DRM
An early strategic planning of all required NBS assessments throughout the CCA/DRM cycle would ensure the necessary flow of information on NBS and its performance from the initial planning and design choices to monitoring and evaluation. It shows to allow both optimal design of NBS based on best available knowledge, continuous monitoring and calibration and may inform NBS upgrades, upscaling and future NBS implementation, as illustrated by the Copenhagen Cloudburst Management Plan and Protective Mountain Forest Management. However, in several other real-life cases the choice of assessment approach (incl. the required assessment characteristics, elements and methods) often evolved or needed to be adjusted over the life time of the project (with increasing experience, knowledge and/or local uptake) and hence could not easily be planned in an early stage (e.g., Elbe Dyke Relocation, Tulltorpsån). Therefore, planning strategically, but allowing for flexibility further down the line may be the most prudent approach.

Multiple entry points in the CCA and DRM cycle
Application of NBS assessment for adaptation to climate change and/or disaster risk reduction (e.g., flood and drought risk management, erosion control, heat resilience) are the common elements in all the surveyed cases. NBS assessments carried out in the analysed in-depth cases have been serving various entry points in the CCA and DRM cycles. In several projects, there is a natural overlap between CCA and DRR activities (e.g., Camargue Saltworks Restoration, Copenhagen Cloudburst Management Plan). Assessment approaches applied in the cases vary from ex-ante (including technical feasibility and effectiveness assessments, and cost-benefits analysis), to operational and ex-post assessments (including indicator-based assessments and monitoring).

In the *ex-ante phase* of the project cycle, assessment approaches were commonly applied in order to identify adaptation (CCA cycle step 3) and/or DRM measures, to provide a robust evidence base about benefits and trade-offs of choosing between different options (green, grey, hybrid) and to assess the technical effectiveness of NBS for risk reduction and enhancing resilience (e.g., by the use of computer-based modelling tools to compare different scenarios or/and options, as illustrated in the Elbe Dyke Relocation and Forest Resilient). Several of the cases explicitly recognise the value of providing assessment data and insights to a wider audience for scale-up and replication purposes (e.g., Elbe Dyke Relocation served as a pilot sites and has been replicated in other sites; or the economic assessment developed in the Copenhagen Cloudburst Management Plan have been an inspiration for national requirements in adaptation strategies and projects). On the other hand, relatively few cases aimed to assess potential costs of implementation and maintenance in support of budget planning or to assess project's economic parameters to build the business case for implementation. The exclusion of the latter in current assessment applications may present a limitation, especially for those situations where the building of a strong business case matters greatly – such as when raising private capital investments or lending for NBS implementation.

In the *operational phase*, assessments are applied during the implementation of the adaptation options (CCA cycle Step 5), including for monitoring and evaluation (CCA cycle Step 6, all stages in DRM cycle), as part of ongoing maintenance and operation of NBS interventions. All case study assessments applied in the operational phase aimed to build an understanding and an evidence base on the functioning of NBS, as well as several assessments were also used to verify the NBS or identify design improvements for possible scale-ups and replications (e.g., Elbe Dyke Relocation). Relatively few cases aimed to use assessments for calibration purposes of models or NBS itself, while none of the cases aimed to explicitly assess and report expenditures and benefit ratios during the NBS operation. As mentioned before, the ongoing exclusion of the economic parameters also in the operational phase assessments may deepen the knowledge gap on the economic performance of NBS as measures for CCA and DRM. The best practice observed in cases suggests that operation phase assessments are an important element for NBS upscaling and replication in a continuous refinement and improvement cycle as we continue to build our understanding on NBS performance.

In the *ex-post phase* of NBS projects, the assessments focussed on monitoring and evaluation of NBS effectiveness and performance (CCA cycle Step 6, post-disaster stage in DRM cycle) (e.g., Barcelona Tree Master Plan, Basel Green Roofs, Protective Mountain Forest Management, Elbe Dyke Relocation). Most cases aimed to specifically assess the risk reduction or resilience increase effects achieved by the implemented NBS. Several cases explicitly aimed to build a knowledge base to inform future designs, funding and implementation approaches. However, none of the cases aimed to assess the return on investment made. Interestingly, only one case evaluated the full societal benefits ex-post through a comparative social cost-benefit assessment (Dijle River Restoration), however, several of the cases indicated plans or the wish to include evaluations of full societal benefits. The reason for not undertaking such an assessments appear to be either a lack of expertise, that the project is not sufficiently advanced enough or a limitation in a national guidance for carrying out socio-economic assessments of public projects. Thus, although the social element is likewise one of the least-assessed, there appears to be clear interest in integrating it in the assessments as it is also the case for the economic element. That may be explained by the intended purposes and planned uses of assessment results, which in the observed cases were often geared towards building the evidence-base for NBS effectiveness and supporting stakeholder communication and public policy design.

Integration of synergistic purposes

Several assessments do not focus on climate impact/risk reduction only, but also considered other synergistic purposes the assessment may serve outside the CCA/DRM realm (multi-purpose assessment). This wider perspective may offer higher efficiencies as one assessment may serve several needs (or purposes) in different policy and decision-making areas and support the buy-in of NBS projects across a wider group of stakeholders. This notion has also been supported by the analysed case studies, which often have been developed with a wider perspective (e.g., to also account for restoring habitats, enhancing biodiversity or/and recreation opportunities). Especially the synergistic link between biodiversity and CCA/DRR is apparent in most cases (e.g., the Elbe Dyke Relocation, Dijle River Restoration, Resilient Forest), although biodiversity was commonly mentioned as an additional benefit rather than a criterion for implementing or denoting NBS in the first place. Other synergistic purposes include supporting environmental management policies (e.g., water quality), physical health and social benefits (e.g., recreation) and job creation (e.g., in tourism, biomass production).

The multi-purpose assessments might require higher levels of collaboration (e.g., between departments working on climate change, biodiversity, health, transport, social aspects etc.), pooling of resources and broader stakeholder engagement but may also build a stronger business case for NBS, as they recognise the multitude of benefits NBS provide beyond their CCA/DRM purpose, thus accentuating NBS advantages over other types of CCA/DRM solutions, which have a more limited scope of co-benefits. These larger cross-department collaborations may likewise allow assembling resources from several budget streams both to support the assessment and also for the implementation of the NBS itself.

Level of stakeholder engagement depends on the purpose
In line with other studies (EC, 2021), our analysis highlights the relevance of co-productive approaches taking into account different knowledge, expertise and lived experiences of many stakeholders, for designing robust NBS impact assessments. Thereby, several iterations might be needed to allow stakeholder involvement in the co-design of the assessment, creation of ownership and care of the NBS measure. The cases illustrate that especially where NBS has an impact on land owners or residents, stakeholder involvement and co-design was key to ensuring understanding, buy-in and ownership, but also to improve the design and the assessment approach (e.g., include assessment purposes that are also in the interest of stakeholders). Where the assessment is of a technical nature and the NBS does not directly have an influence on stakeholders, high levels of involvement, especially of external stakeholders, was not necessarily needed, as it was seen in the case of continuous risk assessments and biodiversity assessments based on monitoring (e.g., the Basel Green Roof, Protective Forest Mountain Management). The highest degree of stakeholder involvement in the purpose and choice of assessments was found in the Tulltorpsån case, where stakeholders (i.e., farmers, local residents) were not only instrumental in identifying and selecting the required assessment approach, but also asked for investigations into the potential impact that the choice of methods would have. The stakeholders initiated and organised the creation of an economic association to enable collaboration among several land owners and to inform a legal entity capable of applying for external funding for carrying out NBS measures along the Tulltorpsån water course.

Closely working with local residents by making use of extensive public consultations and co-creation processes have also proven to lead to strong ownership and care of NBS measures implemented (e.g., Copenhagen Cloudburst Management Plan, Barcelona Tree Master Plan). Involving stakeholders in the initial planning and design choice (e.g., by site visits, workshop, individual meetings) allows project holders to develop a robust and useful assessment which match with stakeholders needs enhancing buy-in and interest in assessment outcomes (e.g., Resilient Forest). These findings in real-life cases reinforce the theoretical framework, which indicates that the considerations on the appropriate level of stakeholder engagement is a key characteristic that needs to be considered and will differ in line with the assessment purpose and planned use of results. Therefore, it cannot be treated as a one-fits-all aspect. Moreover, working in multi-disciplinary teams requires both time and dedicated processes to understand each other and integrate different views, which can be experienced as a barrier to overcome. Hence, NBS projects and related assessments can take years up to decades to reach its full scale of implementation (e.g. Elbe Dyke Relocation).

Lack of assessments accounting for economic and social elements
Although a key argument for NBS is its often presumed cost-effectiveness as compared to a technical solution, the majority of cases expressed NBS benefits in technical and/or (bio)physical terms rather than in economic terms. This suggests that an economic valuation has not been a prerequisite for raising support for an NBS initiative in the investigated cases. It is unclear whether the inclusion of economic indicators in the analysed case assessments would have led to additional positive outcomes. Social benefits and impacts have not been in focus in the investigated cases, although many of them have identified and made some qualitative assessments. However, none of the cases looked specifically at just resilience and how CCA and DRR may or may not impact different groups differently.

Funding & budget

Several NBS cases from the survey described the lack of funding as a common reason for not conducting (desired or additional) assessments. The cases studied in-depth, reported a diversified portfolio of funding sources including local, national and EU funding, and sometimes also private sources. Two cases created associations specifically with the aim to enable them to obtain funding from different sources (Tulltorpsån, Elbe Dyke Relocation). For NBS projects that operate over long time periods and that are dependent on external funding (e.g., Tulltorpsån), the extra time and efforts spent on securing external funding and reporting to funding bodies, especially when multiple funding bodies are involved, can be experienced as a nuisance.

Drivers for NBS assessments

The key motivating drivers for conducting NBS assessments in the cases included specific requirements from funding bodies (e.g., Basel Green Roof, Dijle River Restoration), local and national policy mandates (e.g., Copenhagen Cloudburst management Plan, Protective Forest management) or/and stakeholder demands and questions from the field (e.g., Resilient Forest, Tulltorpsån). Anchoring assessment requirements in local and national policies and funding requirements is therefore an important factor to ensure that assessments are included when planning NBS projects. If NBS assessments are well designed, the generated information can help building political support from local administration up to the highest political level and facilitate the upscaling and replication of NBS measures (e.g., Elbe Dyke Relocation).

In conclusion, successful design and implementation of NBS assessments rely on various aspects to be considered, and the choice of the assessment approach is often based on an iterative process of identifying the purpose, characteristics, elements and approaches of assessments. Particular for the initiation (ex-ante) and/or evaluation (ex-post) of NBS projects, NBS assessments have shown to play a critical role in providing information that is of relevance for stakeholders and for generating awareness, building trust and to showcase the potential for NBS to other sites. Using assessments which allow to account for perspectives that go beyond CCA and DRR (e.g., combination of biodiversity and flood protection) have shown to provide opportunities to enhance the buy-in of NBS projects across a wider group of stakeholders (including political support). Depending on the purpose of the assessments, collaboration among diverse sets of stakeholders can be beneficial to initiate and optimize assessments and NBS measures. However, working in multi-disciplinary teams needs time and the need for it needs to be critically assessed based on assessment purpose and available resources. The importance of NBS assessments to build evidence on technical, environmental, social and economic performance is paramount for replication in similar contexts and up-scaling up to larger scales. The suggested step-wise framework for designing NBS assessments developed in this report is hopefully a useful step in this direction.

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Annex

Annex 1 Purposes, key characteristics and suitable approaches for NBS assessments

Purpose	**Characterisation of assessment requirements**									**Suitable assessment approaches**	
	CCA/DRM cycle phase	**Key required output metrics**	**Time considerations** *(future-looking / current snapshot / past-looking)*	**Comparative?** *(Yes / No)*	**Accounting for uncertainty** *(Important / medium / low)*	**Required completeness and quality of input data** *(low / medium / high)*	**Range of benefit/cost types to be included** *(single / multiple benefits / costs)*	**Spatial scale required** *(plot / local / neighbourhood / regional / national / international)*	**Temporal scale required?** *(one-off / continuous / Yearly / decadal)*	**Approach**	**Case examples**
Ex-ante											
Provide a robust evidence base about the benefits and trade-offs of choosing between different NBS options or between NBS and other CCA/DRM measures	CCA: Step 3 DRM: Prevention	Quantitative: - Technical effectiveness indicators - Resource use requirements (e.g., energy, water) - Costs and economic parameters - Construction time Qualitative: - Maps - Community acceptance - Environmental and social impacts	Future-looking	Yes	Important	Medium	From Single to multiple benefits/costs	Local / Neighbourhood / Plot scale	Yearly to decadal	Technical feasibility & effectiveness assessments / Cost-benefit assessment/ Economic valuation of specific benefits / life-cycle-based assessment/ Multi-criteria assessments / Indicator-based assessments	Tulltorpsån Resilient Forests Camargue Saltworks Restoration Copenhagen Cloudburst Management Dijle river Restoration Elbe Dyke Relocation
Technical effectiveness of NBS for risk reduction/resilience increase in support of the engineering technical design	CCA: Step 4 DRM: Prevention	Quantitative: - Technical effectiveness indicators - Indicators for risk reduction/ resilience increase	Future-looking	Yes	Important	High	Mostly single benefit, but may include more	Local / Plot scale	Yearly to decadal	Technical feasibility & effectiveness assessments / Indicator-based assessments	Camargue Saltworks Restoration Resilient Forests Protective Mountain Forest Management Copenhagen Cloudburst Management

Purpose	Characterisation of assessment requirements									Suitable assessment approaches	
	CCA/DRM cycle phase	**Key required output metrics**	**Time considerations** *(future-looking / current snapshot / past-looking)*	**Comparative?** *(Yes / No)*	**Accounting for uncertainty** *(Important / medium / low)*	**Required completeness and quality of input data** *(low / medium / high)*	**Range of benefit/cost types to be included** *(single / multiple benefits / costs)*	**Spatial scale required** *(plot / local / neighbourhood / regional / national / international)*	**Temporal scale required?** *(one-off / continuous / Yearly / decadal)*	**Approach**	**Case examples**
											Dijle River Restoration Tullstorpsån Elbe Dyke Relocation
Understanding the full range of environmental, economic and societal impacts and benefits of NBS	CCA: Step 4 DRM: Prevention	Quantitative: - Environmental indicators - Economic indicators - Social indicators Qualitative: - Community acceptance - Environmental and social impacts	Future-looking	Yes	Medium	High	Multiple benefits / costs	From plot scale to regional scale	Yearly to decadal	Technical feasibility and effectiveness assessments / Stock-taking / accounting of natural capital and ecosystem services / Stakeholder assessments / Economic valuation of specific benefits / Cost-benefit assessment / Return on investment assessments / Life-cycle-based assessments / Multi-criteria assessments / Indicator-based assessments / Theory of change / Delphi method / Narrative-based approaches	
Assessing the costs of implementation and maintenance in support of budget planning	CCA: Step 4 DRM: Prevention	Quantitative: - Cost indicators for implementation (e.g. construction costs)	Future-looking	Yes	Important	High	Multiple costs	Local / Plot scale	Yearly	Costing / life cycle costing	Tullstorpsån Copenhagen Cloudburst Management Protective Mountain Forest Management

Purpose	Characterisation of assessment requirements									Suitable assessment approaches	
	CCA/DRM cycle phase	**Key required output metrics**	**Time considerations** *(future-looking / current snapshot / past-looking)*	**Comparative?** *(Yes / No)*	**Accounting for uncertainty** *(Important / medium / low)*	**Required completeness and quality of input data** *(low / medium / high)*	**Range of benefit/cost types to be included** *(single / multiple benefits / costs)*	**Spatial scale required** *(plot / local / neighbourhood / regional / national / international)*	**Temporal scale required?** *(one-off / continuous / Yearly / decadal)*	**Approach**	**Case examples**
											Camargue Saltworks Restoration
Assessing project economic parameters (e.g., net present value, cost-effectiveness and cost-benefit ratios) incl. in comparison with other measures to build the business case for NBS implementation	CCA: Step 4 DRM: Prevention	Quantitative: - Economic and cost indicators - Environmental indicators - Social indicators Qualitative: - Community acceptance - Environmental and social impacts	Future-looking	Yes	Important	High	Multiple benefits / costs	Local / Plot scale	Yearly	Economic valuation of specific benefits / Cost-benefit assessment / Return on investment assessments	Protective Forest Mountain Management Copenhagen Cloudburst Management Plan Camargue Saltworks Restoration
Provide data and messaging for communication on the benefits of NBS as adaptation / DRM measures – to aid stakeholder awareness, participation and buy-in	CCA: Step 4 DRM: Prevention	Quantitative: - Environmental indicators - Economic indicators diagrams Qualitative: - Diagrams - Photos - Videos	Current snapshot / Future-looking	Yes	Low	Medium	Multiple benefit / costs	From plot scale to regional scale	One-off, yearly to decadal	Narrative-based approaches / Theory of change	Barcelona Tree Master Plan Elbe Dyke Relocation Camargue Saltworks Restoration
Assessments for carbon or biodiversity credit / offset or compensation schemes	CCA: Step 4 DRM: Prevention	Quantitative: - Environmental indicators (e.g., ecosystem quality, provision of ecosystem services) - Economic indicators (e.g., social cost of carbon, carbon price)	Current snapshot / Future-looking	No	Important	High	Multiple benefit / costs	From plot scale to regional scale	One-off, yearly to decadal	Economic valuation of specific benefits / Cost-benefit assessment / Life-cycle-based assessments / Indicator-based assessments	
Assessments of NBS projects for attracting green/sustainable adaptation/DRM finance	CCA: Step 4 DRM: Prevention	Quantitative: - Environmental indicators - Economic indicators	Current snapshot / Future-looking	Yes	Important	High	Multiple benefit / costs	From plot scale to regional scale	One-off, yearly to decadal	Technical feasibility and effectiveness assessments / Stock-taking / accounting of natural capital and	

Purpose	Characterisation of assessment requirements									Suitable assessment approaches	
	CCA/DRM cycle phase	**Key required output metrics**	**Time considerations** *(future-looking / current snapshot / past-looking)*	**Comparative?** *(Yes / No)*	**Accounting for uncertainty** *(Important / medium / low)*	**Required completeness and quality of input data** *(low / medium / high)*	**Range of benefit/cost types to be included** *(single / multiple benefits / costs)*	**Spatial scale required** *(plot / local / neighbourhood / regional / national / international)*	**Temporal scale required?** *(one-off / continuous / Yearly / decadal)*	**Approach**	**Case examples**
		- Indicators for risk reduction/resilience increase Qualitative: - Community acceptance - Environmental and social impacts								ecosystem services / Stakeholder assessments / Economic valuation of specific benefits / Cost-benefit assessment / Return on investment assessments/ Life-cycle-based assessments / Multi-criteria assessments / Indicator-based assessments	
Operational phase											
For calibration purposes	CCA: Step 6 DRM: assessments as part of ongoing maintenance and operation	Quantitative: - Environmental indicators - Technical effectiveness indicators	Current snapshot	No	Important	High	-	Local / Plot scale	One-off, continuous	Technical feasibility and effectiveness assessments / Indicator-based assessments	Barcelona Tree Master Plan Protective Mountain Forest Management Tullstorpsån Camargue Saltworks Restoration
Building evidence base on the functioning of NBS	CCA: Step 6 DRM: assessments as part of ongoing maintenance and operation	Quantitative: - Environmental indicators - Economic indicators - Technical indicators - Indicators for risk reduction / resilience increase Qualitative: - Community acceptance	Current snapshot	Yes	Important	High	From single to multiple benefits / costs	From plot scale to regional scale	One-off, continuous, yearly to decadal	Technical feasibility and effectiveness assessments / Stock-taking / accounting of natural capital and ecosystem services / Stakeholder assessments / Economic valuation of specific benefits / Cost-benefit assessment / Return on investment	Tulltorpsån Camargue Saltwork Restoration Resilient Forest Barcelona Tree Master Plan Protective Mountain Forest Management

Purpose	Characterisation of assessment requirements									Suitable assessment approaches	
	CCA/DRM cycle phase	**Key required output metrics**	**Time considerations** *(future-looking / current snapshot / past-looking)*	**Comparative?** *(Yes / No)*	**Accounting for uncertainty** *(Important / medium / low)*	**Required completeness and quality of input data** *(low / medium / high)*	**Range of benefit/cost types to be included** *(single / multiple benefits / costs)*	**Spatial scale required** *(plot / local / neighbourhood / regional / national / international)*	**Temporal scale required?** *(one-off / continuous / Yearly / decadal)*	**Approach**	**Case examples**
		- Environmental and social impacts								assessments / Life-cycle-based assessments / Multi-criteria assessments / Indicator-based assessments / Theory of change / Delphi method / Narrative-based approaches	Copenhagen Cloudburst Management Plan Elbe Dyke Relocation Basel Green Roofs Dijle River Restoration
For verification of the design or identification of design improvements and possible scale-up	CCA: Step 6 DRM: assessments as part of ongoing maintenance and operation	Quantitative: - Environmental indicators - Technical effectiveness - Indicators economic indicators	Current snapshot / Future-looking	Yes, if various options are explored	Important	High	Single to multiple cost/benefits	Local / Plot scale	One-off, continuous, yearly	Technical feasibility and effectiveness assessments / Stock-taking/accounting of natural capital and ecosystem services / Economic valuation of specific benefits / Cost-benefit assessment / Indicator-based assessments	Basel Green Roofs Barcelona Tree Master Plan Copenhagen Cloudburst Management Plan Camargue Saltworks Restoration Elbe Dyke Relocation
Assessing and reporting the expenditure and benefits ratios, including for supporting maintenance cost budgeting	CCA: Step 6 DRM: assessments as part of ongoing maintenance and operation	Quantitative: - Costs and economic indicators	Current snapshot / Future-looking	No	Important	High	Multiple costs / benefits	Local / Plot scale	One-off, continuous, yearly	Expenditure accounting, budgeting	
Assessment of the asset value of the NBS for inclusion on the balance sheet	CCA: Step 6 DRM: assessments as part of ongoing maintenance and operation	Quantitative: - Economic indicators	Current snapshot	No	Important	High	In most cases – single benefit in alignment with accounting rules	Plot scale	One-off, yearly	Accounting valuation methods	
Ex-post											

Purpose	Characterisation of assessment requirements									Suitable assessment approaches	
	CCA/DRM cycle phase	**Key required output metrics**	**Time considerations** *(future-looking / current snapshot / past-looking)*	**Comparative?** *(Yes / No)*	**Accounting for uncertainty** *(Important / medium / low)*	**Required completeness and quality of input data** *(low / medium / high)*	**Range of benefit/cost types to be included** *(single / multiple benefits / costs)*	**Spatial scale required** *(plot / local / neighbourhood / regional / national / international)*	**Temporal scale required?** *(one-off / continuous / Yearly / decadal)*	**Approach**	**Case examples**
Assessing the effect achieved of NBS on the climate impact/risk reduction	CCA: Step 6 DRM: Post-disaster evaluation	Quantitative: - Technical effectiveness indicators - Indicators for risk reduction/resilience increase	Past-looking	No	Important	High	Single or multiple benefits depending on number of risks addressed	From plot scale to regional scale	Continuous, yearly to decadal	Technical feasibility and effectiveness assessments / Indicator-based assessments	Protective Mountain Forest Management Copenhagen Cloudburst Management Plan Dijle River Restoration Elbe Dyke Relocation Barcelona Tree Master Plan Basel Green Roofs
Assessing the return on investment made	CCA: Step 6 DRM: Post-disaster evaluation	Quantitative: - Economic indicators	Past-looking	No	Important	High	Single to multiple benefits and costs	Plot scale	One-off, yearly	Return on investment assessments	
Evaluating the full societal benefit achieved across the full range of benefits, costs and dis-benefits of NBS	CCA: Step 6 DRM: Post-disaster evaluation	Quantitative: - Social indicators - Environmental indicators Qualitative: - Community acceptance - Environmental and social impacts	Past-looking	No	Important	High	Multiple benefits and costs	From plot scale to regional scale	Yearly to decadal	Stakeholder assessments / Stock-taking / accounting of natural capital and ecosystem services / Indicator-based assessments / Life-cycle-based assessments / Multi-criteria assessments / Theory of change / Delphi method / Narrative-based approaches	Dijle River Restoration
Knowledge base for informing future designs, funding and implementation approaches for NBS as adaptation/DRM measures	CCA: Step 6 DRM: Post-disaster evaluation / Post-disaster assessment	Quantitative: - Environmental indicators - Economic indicators - Technical indicators	Past-looking	Yes	Important	High	From single to multiple benefits/costs	From plot scale to regional scale	One-off, continuous, yearly to decadal	Technical feasibility and effectiveness assessments / Stock-taking / accounting of natural capital and ecosystem services / Stakeholder assessments / Economic valuation of	Camargue Saltworks Restoration Elbe Dyke Relocation Dijle River Restoration

Purpose	Characterisation of assessment requirements								Suitable assessment approaches	
	CCA/DRM cycle phase	**Key required output metrics**	**Time considerations** *(future-looking / current snapshot / past-looking)*	**Comparative?** *(Yes / No)*	**Accounting for uncertainty** *(Important / medium / low)*	**Required completeness and quality of input data** *(low / medium / high)*	**Range of benefit/cost types to be included** *(single / multiple benefits / costs)*	**Spatial scale required** *(plot / local / neighbourhood / regional / national / international)*	**Temporal scale required?** *(one-off / continuous / Yearly / decadal)*	**Approach**	**Case examples**
		- Indicators for risk reduction / resilience increase Qualitative: - Community acceptance - Environmental and social impacts								specific benefits / Cost-benefit assessment / Return on investment assessments / Life-cycle-based assessments / Multi-criteria assessments / Indicator-based assessments / Theory of change / Delphi method / Narrative-based approaches	Copenhagen Cloudburst Management Plan
Complementary											
Identification and assessment of the co-benefits (e.g., biodiversity, environmental, health, social, economic)	CCA: Step 4 / Step 6 DRM: Prevention / Post-disaster evaluation	Quantitative: - Environmental indicators - Economic indicators - Social indicators (e.g., benefits for wellbeing and health) Qualitative: - Community acceptance - Environmental and social impacts	Future-looking / Past-looking	Yes	Important	High	From single to multiple benefits / costs	From plot scale to regional scale	One-off, continuous, yearly to decadal	Economic valuation of specific benefits / Cost-benefit assessment/ Life-cycle-based assessments / Multi-criteria assessments / Indicator-based assessments / Stakeholder assessments / Stock-taking / accounting of natural capital and ecosystem services / Theory of change / Delphi method	Tulltorpsån Protective Mountain Forest Management Camargue Saltworks Restoration Elbe Dyke Relocation Copenhagen Cloudburst Management Plan Barcelona Tree Master Plan Basel Green Roofs

Purpose	Characterisation of assessment requirements									Suitable assessment approaches	
	CCA/DRM cycle phase	**Key required output metrics**	**Time considerations** *(future-looking / current snapshot / past-looking)*	**Comparative?** *(Yes / No)*	**Accounting for uncertainty** *(Important / medium / low)*	**Required completeness and quality of input data** *(low / medium / high)*	**Range of benefit/cost types to be included** *(single / multiple benefits / costs)*	**Spatial scale required** *(plot / local / neighbourhood / regional / national / international)*	**Temporal scale required?** *(one-off / continuous / Yearly / decadal)*	**Approach**	**Case examples**
Assessments for understanding the land-use related aspects (e.g., trade-offs)	CCA: Step 4 DRM: Prevention	Quantitative: - Environmental indicators - Economic indicators Qualitative: - Maps - Environmental impacts	Future-looking / Past-looking	Yes	Medium	Medium	From single to multiple benefits / costs	From plot scale to regional scale	Yearly to decadal	Stock-taking / accounting of natural capital and ecosystem services / Economic valuation of specific benefits / Cost-benefit assessment / Indicator-based assessments	
Assessments of trickle-down effects in sectors and economy	CCA: Step 4 DRM: Prevention	Quantitative: - Economic indicators	Future-looking / Past-looking	Yes	Important	High	From single to multiple benefits / costs	From plot scale to regional scale	Continuous, yearly to decadal	Life-cycle assessments / Narrative based / Stakeholder assessments / Multi-criteria analyses	
Assessments for the understanding of the cost-bearing and benefit distribution between different stakeholders	CCA: Step 4 DRM: Prevention	Quantitative: - Costs and economic indicators - Environmental indicators	Future-looking / Past-looking	Yes	Important	High	From single to multiple benefits / costs	From plot scale to regional scale	Yearly to decadal	Cost-benefit assessment / Economic valuation of specific benefits	
Integration in environmental-economic accounts aligned with UN SEEA-EA	CCA: Step 4 DRM: Prevention	Quantitative: - Environmental indicators - Economic indicators - Technical indicators	Future-looking	Yes	Important	High	Multiple benefits (ecosystem services)	From plot scale to regional scale	One-off, yearly	Accounting of natural capital and ecosystem services	
NBS contributions to local SDG implementation and overall sustainability enhancements	CCA: Step 4 DRM: Prevention	Quantitative: - Environmental indicators - Economic indicators - Technical indicators - Indicators for risk reduction / resilience increase	Future-looking	Yes	Medium	Medium	From single to multiple benefits	From plot scale to regional scale	Yearly to decadal	Economic valuation of specific benefits / Stakeholder assessments / Indicator-based assessments / Narrative-based approaches	

Purpose	Characterisation of assessment requirements									Suitable assessment approaches	
	CCA/DRM cycle phase	**Key required output metrics**	**Time considerations** *(future-looking / current snapshot / past-looking)*	**Comparative?** *(Yes / No)*	**Accounting for uncertainty** *(Important / medium / low)*	**Required completeness and quality of input data** *(low / medium / high)*	**Range of benefit/cost types to be included** *(single / multiple benefits / costs)*	**Spatial scale required** *(plot / local / neighbourhood / regional / national / international)*	**Temporal scale required?** *(one-off / continuous / Yearly / decadal)*	**Approach**	**Case examples**
		Qualitative: - Community acceptance - Environmental and social impacts									

Annex 2 – E-mail survey

Email text for 1st round NBS survey

Dear xx,
The European Environment Agency (EEA) has come across the project [xx] as part of a screening of interesting cases of how nature-based approaches have been implemented in practice across Europe. The project [name] is part of a total of 97 cases that are analysed in the upcoming EEA report 'Nature-based Solutions and ecosystem-based approaches for climate change adaptation and disaster risk reduction'. The EEA report will be published late April 2021 and we will be happy to send you the link once it is published.

The EEA is interested - through analysis and synthesis of evidence and practice - in supporting the case for nature-based solutions as effective and low-regret ways of solving many societal challenges linked to the environment and climate change in both rural and urban contexts.
We are currently looking into if and how nature-based initiatives in practice have applied assessments and monitoring either before, during or after implementation. The aim of this information is to provide good examples and experience from the field to policy makers across Europe on how to go about deciding on and assessing nature-based projects. The experience from your project is therefore important.
Assessments can be qualitative or quantitative and can help evaluate if a project or initiative is desirable, how to best design and implement it and also to learn from projects after implementation.

We would be very interested to know the following (brief answers are sufficient):

- What was/is the main purpose/benefit of the project?
- What do you consider the main additional benefits of the project?
- Did *you do a qualitative assessment of the project (before, during or after)?*
  - If yes – what type and when in the project cycle?
  - If no – *why did you choose not to a qualitative assessment?*
- Did you do a quantitative assessment of the project (before, during or after)?
  - If yes – what type and when in the project cycle?
  - If no – why did you choose not to a quantitative assessment?
- Do you have or did you have monitoring of how the nature-based initiative works out?
  - If yes, what kind of metric or indicator are you measuring or have you used?
  - If no, why is or was no monitoring put in place?

If you are not specifically involved in this NBS project or initiative, could you please point us the correct person(s) to be contacted?

We look very much forward to receiving your response.

Best wishes.

Annex 3 - Interview guide: deployment of assessments in NBS projects for CCA/DRR

DRR/Adaptation project

1. **Was adaptation/DRR the main purpose of the project?**
   a. If not, what was the main purpose of the project? What role does adaptation/DRR play [we will seek to select cases where adaptation/DRR is reported as main purpose, this is just to check that]
2. **Do you perceive your project to be part of adaptation to climate change or to disaster risk management?** (or both?)
3. **What type of decisions/policies did the assessment aim to support?**

Funding and budget

4. **What type of funding has been deployed in the project?**
5. **How was the assessment budgeted/foreseen/negotiated in the NBS planning?**
6. **Are there any provisions/structures in place for carrying out long-term assessments?**

Purpose of assessment method

7. **What was the main purpose of the NBS assessment(s)?**
   a. Assessment entry Steps in Adaptation cycle:
      i. Identifying adaptation options
      ii. Assessing adaptation options
      iii. Monitoring and evaluation
   b. Assessment entry Steps in DRM cycle:
      i. Planning and implementation of NBS
      ii. Assessments as part of ongoing maintenance and operations; post-disaster evaluation of NBS effectiveness
      iii. Post-disaster assessment of needs of NBS improvements or additional NBS
   c. **What additional purposes did the NBS assessment include or contribute to?** [check/establish for which key societal challenge the assessments help shed light on:]
      i. Water Management
      ii. Green Space Management
      iii. Biodiversity Enhancement
      iv. Air Quality
      v. Place Regeneration
      vi. Knowledge and Social Capacity Building for Sustainable Urban Transformation
      vii. Social Justice and Social Cohesion
      viii. Health and Wellbeing
      ix. New Economic Opportunities and Green Jobs

Assessment methods applied

8. **What kind of NBS impact did the assessment(s) cover?**
      i. Technical/physical NBS impact
      ii. Economic impact
      iii. Human/social/cultural impact
      iv. Environmental impact
9. **What phases did the assessment(s) apply to?**
10. **Could you better describe the main applied assessment method and the NBS impact you were interested?**
    A. **Stock-taking/accounting** of the existing natural capital and its ecosystem services (mapping, GIS, inventories)
    B. **Technical feasibility** and **effectiveness** assessments (literature based, inventories, sensor and monitoring data, modelling)
    C. **Cost-benefit** assessments (CBA-based: cost-benefit assessment, Cost-effectiveness assessment

D. **Economic valuation** of specific benefits (use of environmental economics methods: contingent valuation/stated preference (e.g., willingness to pay, trade-off game, costless-choice), revealed preference (e.g., travel-cost method, hedonic pricing, preventive expenditure, preventive markets, etc.), benefit transfer and others)
E. **Return on investment** assessments (net present value, internal rate of return, payback time, etc.)
F. **Holistic life-cycle-**based impact assessments (life-cycle assessments, life-cycle costing, social-LCA, life cycle sustainability assessments)
G. **Multi-criteria** assessments (stakeholder or expert based)
H. **Indicator-based** assessments
I. **Stakeholder** assessments
J. **Narrative**-based approaches storylines
K. **Other** approaches: theory of change, Delphi method

11. **Did you consider other types of assessments too?**
12. **What are the key characteristics of the different assessments you applied? For a) main assessment and b) other assessments:**

Technical/physical

*Characteristics of **indicators***:

1. Qualitative / quantitative data
2. Spatial/temporal
3. Linked to economic and monetary aspects/linked to natural science
4. Ex-ante/on-going/ex pos

*Characteristics of **methods** used:*

1. In-situ measurement
2. Remote sensing
3. Modelling of natural processes
4. Risk assessments
5. Other

Economic impact

*Characteristics of **indicators***:

1. Qualitative / quantitative data
2. Spatial/temporal
3. Linked to economic and monetary aspects/linked to natural science
4. Ex-ante/on-going/ex post

*Characteristics of **methods** used*

1. Economic valuation of benefits from ecosystem services
2. Market values
3. Non-market values (stated preference; revealed preference)
4. Cost effectiveness
5. Return on Investment
6. Other

Human/Social/cultural impact

*Characteristics of **indicators***:

1. Qualitative / quantitative data
2. Spatial/temporal
3. Linked to economic and monetary aspects/linked to natural science
4. Ex-ante/on-going/ex post

*Characteristics of **methods** used:*

1. Benefits from ESS
2. Health
3. Acceptance
4. Employment & income
5. Other

13. **What type of output did the assessment provide?**

    a. Why did you choose this particular output and how was it helpful for your purpose of the assessment?

Drivers of assessment

14. **What was the reason for choosing the given assessment method?**
    a. Where any of these reasons limiting the choice of your assessment? (e.g.,map – GIS expertise or maps available; lack of sensors...)
15. **How have the assessment results been used?**
    a. How was the purpose useful?
    b. How were outputs used/fed into other decisions or projects?) [to exclude checklists – process monitoring – we focus on output monitoring]

Barriers/success factors

16. **What barriers have you experienced in planning for and conducting the assessments and getting buy-in for the results?**
17. **What do you see as the success factors in conducting the assessments and getting buy-in for the results?**

Social vulnerability & Stakeholder involvement

18. **Have stakeholders been involved in the assessment of the project or in the project planning and design?**
    a. Who
    b. How
    c. When in the process
19. **Does your assessment take specifically social vulnerability into account**

Annex 4 – In-depth case descriptions

This annex provides summary descriptions of the in-depth case studies, case by case.

Name of case: Barcelona Tree Masterplan, Spain

Contact people: Izaskun Martí Carral and Gabino Carballo (Direcció de Serveis Tècnics i Planificació, Barcelona Municipality).
Country: Spain.
Climate impacts: Regulation of temperatures.

Brief about the case: Barcelona is particularly vulnerable to climate change. Its high population density also magnifies the local heat island effect, which causes an array of health and environmental challenges. Climate change projections include a rise in average temperature and a significant decrease in rainfall, with expected lasting droughts and intense heat waves. In response, Barcelona has committed to becoming a global model of a sustainable city combating urban development challenges related to climate change and population density. In this context, Barcelona has been focusing on planting and managing trees for many years and developed the "Trees for living. Barcelona Tree Master Plan 2017-37", in lines with the goal of the Barcelona Green Infrastructure and Biodiversity Plan 2020 (BGIBP). The Barcelona Tree Master Plan aligns its objectives with the wider City development objectives, making the Barcelona Tree Master Plan far more than a tree management plan.

Photo: Roy, Barcelona Municipality

Role of Adaptation / DRR: Climate adaptation is one of 5 main objectives in the Barcelona Tree Master Plan 2017-2037. The five objectives include i) generate real green infrastructure that achieves the maximum value and connectivity with its urban and natural surroundings; ii) improve both the urban and natural environment; iii) obtain maximum possible ecosystem services from trees including a high level of biodiversity and ensuring good conditions that are felt safe and enhance identity; iv) develop a biomass that is **adapted, resilient and which can be used as a measure to adapt to climate change**; and v) obtain good co-existence between the general public and trees, and encourage society to value trees more from a socio-cultural objective.

NBS measures implemented: NBS measures implemented include the selection, afforestation and management of urban trees. The climate adaptation benefits include modifying the urban microclimate and tempering the climate conditions by providing cooling through shade and transpiration. In addition, the reflection of sunlight by the leaves lowers the temperature in pedestrian areas and the shade protects people from the sun, especially during the hottest months. Furthermore, urban trees can prevent possible local flooding by helping to reduce the amount of storm water runoff.

Type of NBS assessment implemented: Barcelona conducts a lot of systematic assessments both on the trees (health, biodiversity, risks, nuisances) and on the impacts of trees on environmental indicators (temperature, air quality, water management) over many years. Assessments relating to trees are conducted by the Department of Technical Services and Parcs, while the environmental indicators are monitored by the Environment Agency.
Technical/physical NBS impact assessments: Barcelona conducts a systematic 2-year cycle of stock-taking and accounting, recording the number of trees, the condition of trees, the number of incidents, complaints from neighbours (indicator of quality), trees collapsing and branches dropping, as well as allergens and other nuisances. Evaluation of every single tree is also conducted in a 2-year cycle to assess the health, safety and management needs of the trees. Safety is of utmost importance in this tree dense city.
Indicators: The Technical/physical assessments take place in the operational phase and include both qualitative and quantitative data that is spatially and temporally specific and linked to natural science.
Methods: The methods are based on in-situ measurements and are risk based. Most of the assessments are indicator-based. Tools include mapping, GIS and inventories. The Department is starting to assess the variability of data based on some modelling. Sensors are not used extensively and 3D modelling is not (yet) in use in this field. Stakeholder assessments are collated through a registration system of complaints that can point to areas with a problem (even if perceived) and functions as an effective indicator. The Department explicitly uses a strong narrative-based approach on biodiversity to keep informing people about why biodiversity is good and why it's good to have birds and insects in the vicinity of where people live. Life-cycle assessments has become part of Spanish Law and the Department is very interested in this. Multi-criteria assessments are typically done in SUDS projects in the implementation phase, but not yet with urban tree plans, but is increasingly recognised. Unformalised, long-term knowledge of the people working in the Department is central to assessments, adding critical context and experience to data and tools.
Economic impact: The City plans to appraise the economic impacts of the urban trees. The tools and indicators are not in place yet, but it's in the plans to evaluate this.
Human/social/cultural impacts: This topic is included in the plan, but is not currently followed-up.
Environmental impact: Assessments on the quality of air, including PM10, and temperature are closely monitored by the Environment Agency. Monitoring the urban heat island effect is ongoing. VOCs from trees are not monitored. A study carried out years past found that only few of the species cause this problem. Compared to other sources, trees were found to contribute only negligibly and hence this kind of assessment is stopped.
The Department of technical services and planning has a strong biodiversity monitoring programme with several plans of action butterflies, birds, pest insects. The city uses biological control only.
Recently, an atlas of biodiversity in Barcelona has been launched to check the presence and approximate numbers. This will be used in future to assess whether and how the trees contribute to enhancing biodiversity.

Purpose of NBS assessment: The main purpose of the NBS assessment relate to the adaptation cycle. The entry Steps involve "assessing adaptation options" and "monitoring and evaluation". For the "monitoring and evaluation" the City conducts both qualitative and quantitative risk assessments. An emphasis is on risk assessment on the health and safety of the trees related to the management of trees. This is gathered in an extensive database that is used in the "assessing adaptation options" Step, where the City conducts quantitative regression analysis to understand correlations between tree species and health and risk challenges (allergies, branch falling, pests) to continuously improve on the selection and location of tree species and keep track of how trees develop.
Besides CCA, the assessments included following additional purposes: i) water management (results of their work show an overall declining or constant water consumption for trees despite a significant increase in green infrastructure and a need to water individual trees longer. Current water consumption levels are considered low); ii) green space management; iii) biodiversity enhancement; iv) air quality; v) place regeneration (as part of urban design); vi) knowledge and social capacity building for sustainable urban transformation (through consultation with road engineers and architects); viii) health and wellbeing.

Drivers of assessment (reason for choosing the method) : The reason for choosing this finely meshed, thorough and systematic monitoring of all trees in the city is effectiveness in ensuring safety for people. Fatalities are very rare and have serious legal ramifications. The continued and systematic monitoring of trees helps assure the Department they reduce safety risks to a minimum and ultimately secures the continuation of the Tree Master Plan.

Photo: Roy, Barcelona Municipality

Although budgets could be larger to accompany the growing number of trees, the Department has an optimal monitoring and assessment in place.

Use of assessment outputs : Monthly reporting is made to higher management. When trends are identified, action is considered, e.g.,less planting of a species or more pruning. Every year, challenges are revisited and updated. This is predominantly for internal use. The knowledge accumulated and active in the Department is frequently demanded by cities in similar climatic zones, but strategic documentation for external use is not developed. The Department is very active presenting in workshops and conferences. The City assesses the progress and impacts of the Master Plan during the operational phase, which runs until 2037. The City uses the assessments to improve decision making in relation to urban design, urban planning, to increase resource efficiency and recourse consumption. The assessments keep track of how far the City is from meeting challenges for 2037 (indicators of progress): increase 5% of green coverage in the city; increase the city's tree cover by 5% to achieve 30% of the city surface covered by tree canopy, at least 40% of species adapted to climate changes (today 30% level adaptation), reduce the presence of a given tree species to max. 15% of the total population within the urban area to increase biodiversity (increases resilience towards pests), and ensure that all children in primary schools appreciate and can identify the trees in their neighbourhood.
An inventory of species has been made over several years. All decisions are based on data and experience.

Funding and budget: The funding is public and the tree planting, monitoring and maintenance is part of the general budget of the Department. The budget is renegotiated annually. Despite the ambitious implementation to expand the number of trees and increase the biodiversity and resilience of the tree stock in the city, budgets tend to remain constant.

Provisions/structures in place for carrying out long-term assessments: Long term funding is made available for the systematic assessment of trees in Barcelona as well as the monitoring of air quality, temperatures and water management. A tree assessment team working around the clock ensures the continuous focus

Vulnerability and stakeholder involvement: Before the Master Tree Plan came into force in 2017, the City had an extensive and thorough consultation and debate with stakeholders. This included citizens, people working in the streets, architects, water managers, staff monitoring and analysing air quality and engineers and technical staff responsible for lighting and other urban services – basically any place with a potential for conflict.
The systematic registration of all complaints regarding real or perceived nuisances with trees ensures the city is able to always address and be in contact with residents.

Barriers & success factors for the NBS assessments: *Barriers:* Budgets do not necessarily follow the increased workload with systematically assessing a growing number of trees. One barrier is the inability to increase expenditure and push the budget beyond the current level. Technical knowledge may limit the possibility to expand the team, if budgets would allow this. *Success factors:* Absence of serious incidents and not having personal injuries is the main success factor. The general perception among residents is that Barcelona has a lot of trees, are general satisfied with the current canopy, but that in general they would like more trees. Having a very compact city with a huge amount of cities is considered an asset both in the news and among architects in Barcelona. Local politicians can see the value of the systematic assessments in managing risks and nuisances, which results in fewer hazards, fewer complaints compared to cities without similar assessment and monitoring. The long-term Barcelona Tree Master Plan 2017-2035 ensures a continued focus on achieving the objectives with urban trees that is less dependent upon political short-term cycles.

Name of case: Protective Mountain Forest Management, Switzerland

Country: Switzerland.
Contact person: Luuk Dorren (Bern University of Applied Science – BFH).
Climate impacts: Rockfalls, landslides, avalanches.

Brief about the case: Forests can provide effective protection against natural hazards typical occurring in mountains regions (i.e., rockfalls, landslides and avalanches). By preserving and actively managing the forest, this function can be maintained, and people are prevented from getting injured or killed, or infrastructures (e.g., roads, buildings) being damaged. The Engadin case is an example of the many ongoing projects of protection forest management in Switzerland. The use of NBS is part of the Swiss integrated risk management (other elements are proper land-use planning (e.g., by use of hazards maps), and organization measures (e.g., early warning, evacuation, closing of the road). Technical measures (e.g., nets) can also play a role.

Role of climate change adaptation (CCA) / Disaster Risk Reduction (DRR): The main purpose of the protection forest management is DRR, but CCA is continuously discussed in terms of how the management strategy can be improved to be adaptive to climate change (e.g., re-calculation of mud/water reservoirs, selection of tree species).

NBS measures implemented: protection forest management (PFM), which includes silvo-cultural interventions (i.e., practice of controlling the growth, composition/structure, and quality of the forest to meet certain values and needs).

Type of NBS assessment implemented: technical/physical NBS impact assessment (baseline assessment (ex-ante), monitoring (ongoing)): assess state of the forests, defines targets and estimates impacts of potential interventions (e.g., removing trees, planting trees, placing nets), and related costs. Main methods include effectiveness assessments (e.g., modelling (e.g., impact with and without NBS), remote sensing data (e.g., national hazard map), in-situ measurements (monitoring & example plots)) and indicator-based assessments (e.g., very detailed forest check/guidelines). Economic assessment (ex-ante): primarily only done for technical measures, including cost-benefit analysis; benefit-cost ratio for NBS is known to be adequate.

Purpose of NBS assessment: planning and implementation of NBS; assessments are part of ongoing maintenance and operations, post-disaster evaluation of NBS effectiveness; post-disaster assessment of needs of NBS improvement or additional measures; the primary purpose is DRR but increasing attention to also account for additional benefits (wood production, biodiversity, recreation) and to integrate into assessment.

Drivers of assessment (reason for choosing the method): national guidelines, practicality (e.g., sample plots are selected to represent certain conditions, as not everything can be measured everywhere).

Use of assessment outputs: support of daily forest management; communication to public; support to re-define regional and national strategies if needed.

Funding and budget: PFM is financed by the region (Canton) and country with 160 million every year. For each project, including the actual intervention (i.e., keeping the forest in a healthy state to meet the objectives of PFM) and monitoring and evaluation, 40% of the budget is from the country, 40% from the region and 20% from the local community where the intervention is happening. The owner of the forest does not have to pay anything. On average, interventions are taking place every 15-20 years after a disaster event, and every 5 years monitoring. The monitoring is done by local forest managers, paid by the commune, and controlled/checked by region/national agencies.

Vulnerability and stakeholder involvement: no stakeholder involvement, but when interventions are closer to the city is recognized that there is a need for more communication towards citizens to enhance acceptance and raise awareness of SFM.

Barriers/challenges & success factors: *challenges*: sometimes local forest manager does not apply national guidelines and cut more trees than allowed (to sell the wood). Projects are controlled by 'sample checks' (supervision region); budget (priority where highest risk reduction is needed); *success*: collaboration, sharing experiences (e.g., regular meeting with representatives from every region (Canton) to share experiences and discuss current issues such as climate change and how to improve the forest management), teaching and training, history/tradition (long tradition of forest management in Switzerland where already in the eighties a re-thinking of natural hazards management took place, from 'control of nature' towards optimization of natural forest functions), national guidelines and norms.

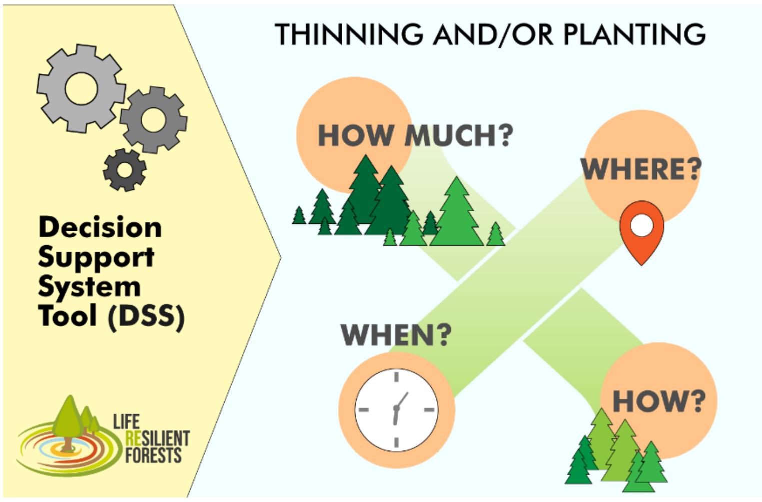
Name of case: Resilient Forests, Germany, Spain, Portugal https://www.resilientforest.eu/

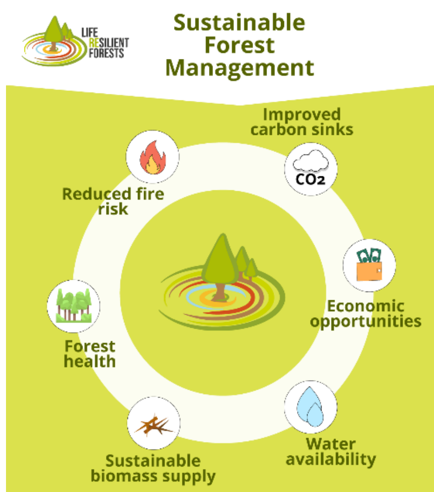
Country: Spain, Germany and Portugal.
Contact person: Mária del Carmen González Sanchis (Universitat Politècnica de València, Department of Hydraulic Egineering and Environment)
Climate impacts: flood, drought, wildfire.

Brief about the case: The RESILENT FOREST promotes sustainable forest management at the watershed scale to improve forests resilience to wildfires, water scarcity, environmental degradation and other effects induced by climate change while enhancing biomass production. The project works with different case study sites, facing different climate change challenges. The main output of the project is a Decision Support System (DSS) tool to introduce forest managers to the climate change adaptation process. The DSS tool allows forest managers to select their objectives and chose the optimum management approach to reach then.

Role of climate change adaptation / disaster risk reduction: Both, CCA and DRR, are the main purposes of the project, as "nowadays you cannot think about forest management without thinking about climate change" (M. González Sanchis).

NBS measures implemented: Sustainable Forest Management (SFM).





Type of NBS assessment implemented: technical/physical NBS impact assessments (=DSS tool) which quantifies the ecosystem services (ES) provided by forests under different management schemes (ex-ante). The tool is based on qualitative (workshops with stakeholders, interviews) and quantitative assessment methods (in-situ measurements (e.g., hydrology, soil measurements, monitoring), mechanistic modelling). Modelling is a key method; it quantifies current ES and optimize ES provision based on multiple criteria (multi-criteria modelling). Thereby the model makes use of spatial and temporal quantitative data (e.g., satellite data). The project plans to add an economic valuation (e.g., cost-benefits of forest management options) to the tool in a later stage of the project.

Purpose of NBS assessment: identifying and assessing adaptation option (by optimizing forest ES related to water, fire, resilience, carbon, energy, timber and biodiversity), planning and implementation of SFM; there are also plans to expand the tool to account for monetarization of benefits, costs (operational), potential job creation.

Drivers of assessment (reason for choosing the method: knowledge/research background & motivation to apply research; demand/question from the field (forest managers ask researchers for help as they struggled with (expensive) forest management, research brought in the idea of SFM).

Use of assessment outputs. The main purpose of the project is to develop the DSS tool, to be used by forest managers; The tool creates GIS-based SF management map (e.g., how to manage, which ES provided etc.) as a final output. The aim of the tool is to reinforce the need for SFM to face climate change among forest managers and (EU) policy makers; The tool is still in development, but already successfully applied in varies areas. Especially the quantification of forest ES (first Step in the tool; 'to see what is going on in the selected forest site', and 'what is happening with climate change') seems to be a useful assessment method to forest managers to recognize the multiple ES (beside timber) and to develop a broader view on the forest. A regional government in Spain generated a funding line based on the results of the quantification.

Funding and budget: The project is co-funded by the European Union's LIFE programme (60%) and (private) partners (40%); Most money is assigned to the DSS tool and to apply it in different case studies. Before the project started, a budget plan was developed. There are plans to use the tool also after the project is finished, and to further adapt and expand (e.g., focus on other aspects of the landscape) the tool. E.g., a new project evolved from the project and new experimental plots are installed in a new area.

Photo: M. González Sanchis

Vulnerability and stakeholder involvement: From the start of the project stakeholder involvement (through workshops, individual meetings) was key to the development of the DSS tool; stakeholders are from public administration (e.g., regional government, city hall) and private forest owners. No social vulnerability assessments.

Barriers & success factors: *Challenge:* The COVID situation was/is a challenge to reach out to stakeholders (which are essential to develop the tool & to disseminate the work); Another challenge was the working together (e.g., understanding each other), especially in the beginning, due to different backgrounds (e.g., scientific, culture, science vs application, context; 'it produces some delay in the project'); and the modelling work (to represent reality within the technical possibilities); *Success:* the work with the stakeholders. It was not only a "great learning experience" among project member (e.g., had to learn how to deal with a wide spectrum of (unexpected) perspectives), but it also made the tool really useful and applicable to the field, stakeholders buy-in the results and get interested in SFM. This is underlined by the interest in the tool by many different stakeholders, also from outside the project.

Name of case: Cloudburst Management Plan, Copenhagen

Country: Denmark.
Contact person: Jan Rasmussen (Teknik & Miljø – Center for bydækkende strategier, Klima og Byrum, Copenhagen Municipality).
Climate impacts: Pluvial flooding, cloudburst.

Brief about the case: After the devastating cloudburst event in 2011 that caused massive private and public asset damages, the Municipality of Copenhagen developed a Cloudburst Management Plan in 2012 to combat the impacts of future cloudbursts. The Plan is an extension of the Copenhagen Climate Adaptation Plan from 2010 that identifies future climate risks, outlines the priorities and measures recommended for climate adaptation including extreme rainfall.
The Cloudburst Management Plan forms a strategy that identifies the optimal level of risk from cloudbursts that the city should adapt to and what measures would be the most cost-effective to achieve that. The Plan concludes that a service level at 1:100 year event is the most cost-efficient adaptation level.
As part of the Cloudburst Management Plan, the City carried out an overall socio-economic risk assessment comparing traditional grey engineering solutions and NBS adaptation measures in reducing the economic loss of assets, loss of property values, working place losses and delays in traffic for a 1:100 year event. The analysis did not include non-market benefits of NBS or avoided damages to cultural values, human lives and health. The assessment showed that continuing to focus on traditional sewage systems would result in a negative societal gain: despite capital investments, financial damages from flooding would remain high and not justify the high investment in implementing grey measures. The chosen combined solution consists of separating rainwater from the sewer network and establish around 300 surface projects, NBS and hybrid NBS solutions, focusing on water retention and drainage. Implementation started in 2015 and is expected to be finalised by 2035.
The Municipality collaborates closely with neighbouring municipalities on addressing cloudburst and flood risks i.a. the comprehensive climate adaptation plan for the stream of Harrestrup is one example of successful collaboration across municipalities.

Role of Adaptation / DRR: Main objectives are related to adaptation of climate change – securing the city against damages from cloudburst events at a 1:100 year level using NBS and hybrid NBS solutions. Additional objectives include creating an attractive greener city with more recreational opportunities and more biodiversity that also helps attract new citizens and investments to the city.

NBS measures implemented: NBS measures implemented contribute to reduce flood peak reduction, increase infiltration and water storage, reduce the load to the sewer system and reduce run-off. The NBS measures implemented improve the connectivity and functionality of green and blue infrastructures, increase biodiversity through the increased quality and quantity of green and blue infrastructures.

Type of NBS assessment implemented: Technical/physical impacts - The city is split up in 7 catchments and for each catchment a detailed risk assessment plan was made. Physical impacts are modelled ex ante using detailed coupled-physics based models of hydrology (MIKE-SHE). Resolution is at a very fine scale (20x20cm), which allows for a detailed modelling of hydrology and avoids over-dimensioning surface solutions and mis-investments. Models are analysed in spatial and temporal resolution, taking into account uncertainty. The technical and physical impacts are revised every 4 years to align with latest scenarios.
Economic impacts - Ex-ante social cost-benefit analysis was carried out for the whole of Copenhagen and Frederiksberg Municipality for the Cloudburst plan. Economic impacts include traffic delay, loss or damage of assets and cost of implementation. The assessment found that by combining traditional grey solutions (pipes) with surface solutions, the city would achieve a socio-economic net benefit of 5 billion DKK (670 Mio. EUR), which is 9 billion DKK (1.2 billion EUR) more than if the Cloudburst Plan were to be realised with only grey solutions.
Economic cost-effectiveness impacts of individual projects are made within each of the 7 catchments to assess the cost-effectiveness of different alternatives (grey versus NBS). A total of 300 projects in

Copenhagen Municipality has been identified, which will be carried out over a period of 20 years (ending by 2035).
Also, an analysis was made to estimate the costs of the Cloudburst plan for households, who pays for the implementation through the utility bills. Findings show an initial annual cost of 1000kr per year per household, and decreasing over time.
Environmental impacts - Environmental impact assessments during the operation phase of the surface solutions are underway as a pilot, especially in relation to impacts of NBS and other surface solutions on water quality under the WFD.

Purpose of NBS assessment: "Assessing adaptation options" was the main entry Step of the socio-economic assessment in the adaptation cycle. The Climate Adaptation Plan had already identified the adaptation options. The Cloudburst Management Plan assessed the socio-economic performance of the different adaptation options at city level, and detailed risk assessment plans including cost-effectiveness analysis are carried out at catchment level within the city. "Monitoring and evaluation" constitutes the second entry Step of relevance in the adaptation cycle. Main entry Steps of the assessment in the DRM cycle are: (i) planning and implementation of NBS and (ii) assessments as part of ongoing maintenance and operations.
Besides CCA and DRR, the assessment included following additional purposes: i) water management; and ii) green space management. In relation to biodiversity, the municipality is currently considering applying for fund to monitor biodiversity improvements in areas where de-pavement or rewilding have already been implemented.

Following aspects were considered as secondary/indirect purposes of the assessment:

- **Place regeneration**: The implementation of the Cloudburst Management Plan is integrated with wider regeneration planning and funding of neighbourhoods in need of improvements.
- **Knowledge and social capacity building for sustainable urban transformation**: Citizen groups in the neighbourhoods are invited for hearing phases and providing input to how to design the NBS for additional benefits of residents.
- **Social justice and social cohesion**: Several of the NBS projects are integrated with city renewal plans (Områdeløft Københavns Kommune) and prove to be a success in generating local ownership. One example include 'Sydhavnen' (South Harbour neighbourhood) where the implementation of seven basins for retaining stormwater was combined with different types of lower-lying gardens and play grounds, developed in co-creation with citizen groups in the design and implementation phase. The process resulting in a strong sense of ownership, where concerns for garbage filling up the basins didn't manifest as the residents take real care of the area; and
- **New economic opportunities and green jobs**: Copenhagen Municipality also aims for export of new methods and experiences to be part of the Cloudburst Plan. Several international collaborations are in place with cities such as New York, Buenos Aires and Beijing, where Copenhagen provides planning and consultancy services. Also, many delegations have visited Copenhagen since 2012 to learn from experiences of implementation of NBS.

Drivers of assessment (reason for choosing the method): The focus in the Cloudburst Plan of including NBS and surface solutions was to generate added value, no-regrets and synergies with other urban agendas in Copenhagen. NBS for CCA/DRR support the long-time aim of increasing green and recreative opportunities in the city. As the cloudburst solutions are not in use very often, it was important for the city to design solutions that provide added values. In fact, Copenhagen strive to create solutions where it's not visually obvious that the implemented solutions are cloudburst solutions. Examples of this can be found in Skt Annae square and Skt. Kjelds neighbourhood.
The development of the initial assessments after the extreme cloudburst event in 2011 were characterized with very little time to develop the plan. In order to address the inherent uncertainties in such plans, the city carries out cost-effectiveness assessments at 62 smaller catchments to make sure the plans are feasible, cost-effective and optimal. This requires very detailed and robust data of the city.

The detailed plans and analyses allows the city to avoid mis-investment and ensure optimal protection. The municipality estimate spending about 2.6 mio. EUR on developing the Cloudburst Plan and detailed analyses, compared to the total investment of implementing the plan of up to 1.6 bio. EUR.

Use of assessment outputs: The Cloudburst Plan aimed at establishing the most cost-effective way to address future cloud bursts and what should be the optimal service level and to provide the basis for decision-making on CCA/DRR. The methodology developed and applied 2011-2015 has fed into the recent regulation on socio-economic assessments of adaptation and other municipalities have been inspired to carrying out similar analyses.

The plan concludes that a service level at 1:100 year event is the most cost-efficient. Three levels of assessments are in place: i) a socio-economic assessment at city-level and ii) cost effectiveness analysis of projects to handle cloudbursts and rain water for 7 catchments (Konkretiseringsplaner); iii) detailed cost effectiveness analysis on small catchment level (62 sub-catchments) in order to ensure up-to-date calculations at a more precise level.

i) At city level, the Municipality estimated the socio-economic costs and benefits of the Cloudburst Plan. The analysis was purely an economic risk analysis that includes loss of assets, loss of property values, working place losses, and delays in traffic. The analysis for instance did not include the avoided damages to cultural values, human lives and health or other multiple benefits from surface solutions compared to grey solutions. The square meter value of property in the municipality does not differ significantly across the municipality, which is why the Cloudburst Plan concluded the most optimal level of protection would be an equal level of protection for all.
ii) A detailed cost-effectiveness analysis was carried out for 7 catchment areas. For each of the identified projects within the 7 catchment areas, the Municipality calculated what would be the concrete costs for ensuring the agreed-upon service level and the operational costs, comparing traditional, grey solutions with NBS.
iii) The detailed cost-effectiveness analysis for the 7 catchment areas are supplemented and revised with local estimations of cost-effectiveness in 62 catchments shortly before actual implementation.

The Cloudburst Plan assessment also aimed to enhance collaboration across neighbouring municipalities, which is of utmost importance. Harrestrup Å is one example of successful collaboration across municipalities. Here, a comprehensive plan has been made w.r.t. climate adaptation.

Funding and budget: The Municipality funded the socio-economic assessment, the Cloudburst Management Plan and subsequent concretization of measures at neighbourhood level at its own initiative and before any requirements or national guidance was in place.

The assessment was budgeted and negotiated in a Step-by-Step approach. First, the administration asked for funds to develop the CCA plan. Then funds were released to develop the strategic cloudburst plan that deals with handling cloudbursts and rainwater. Following this, the administration was granted funds to make the detailed plan at neighbourhood level (7 catchment areas).

At implementation level, total investments are estimated to be between 1.6 and 1.8 billion euros (2011 prices). Currently, about 20-30% of the plan is implemented. The water utility company is responsible for funding the hydraulic part of the solutions (ca. 92% of investment costs), while the municipality funds the 'green' part of the solutions (ca. 8% of the budget). The water utility company covers the costs via the utility bills.

Operational costs of the surface NBS and hybrid NBS solutions are still unknown and need to be based on experience, especially understanding how to split operational costs for managing traditional green infrastructure and operational costs of securing that the CCA part of the green infrastructure functions optimally.

Long-term assessments of the effectiveness of the NBS and hybrid solutions is underway. Physical monitoring is needed to better understand how best to operate the solutions. With more than 300 projects across the city, once the implementation is complete, the city cannot regularly check manually on each location. Pilot projects are therefore in place to test how best to measure whether the solutions hold water, understand level of water flow, how the ground water level develops, and the quality of the surface water being led to the water courses and the sea. This will be expanded to all 300 projects to allow for online monitoring and long-term impact assessment of these solutions. Although the solutions are designed to withstand a 1:100 year event and the full scale of the solutions will occur only rarely, the solutions are designed to also handle everyday rain. In addition to understanding the effectiveness of the solutions, the Municipality also needs to document that the quality of surface water handled in the surface solutions does not reduce water quality in streams, lakes and the sea under the EU Water Quality Framework Directive.

Provisions/structures in place for carrying out long-term assessments: Currently, the Municipality is running a pilot project to monitor the physical effectiveness of the solutions to mainstream maintenance of the 300 projects. The pilot tests different types of monitoring and documentation of water flows and the long-term effectiveness of the solutions. The monitoring needs to document the effectiveness of both everyday rain and the extreme, and more seldom, events like cloudbursts. The pilot also addresses the need to monitor water quality flowing from surface solutions and NBS to waterways and the sea.
The municipality is also considering monitoring of biodiversity on implemented NBS involving de-pavement and rewilding.

Vulnerability and stakeholder involvement: Stakeholder involvement - Stakeholders in terms of citizens and organisations have been involved in the hearing phase of the Cloudburst plan and local residents are systematically involved in co-creation and co-design processes at neighbourhood level in the implementation phase of NBS and surface solutions.
Social vulnerability - The socio-economic assessment does not address aspects of social vulnerability. The data is based on insurance losses per square meter, which is relatively homogenous across the municipality. However, there are differences in impacts of losses relative to income. This would be good to incorporate, especially in areas that are not very homogenous.

Barriers & success factors for the NBS assessments: Barriers - *Water Framework Directive* - A challenging aspect of implementing NBS at systemic scale to handle everyday rain and cloudbursts across a large city is ensuring that water quality respects the Water Framework Directive. The current legislative set up is such that if the city were to not implement adaptation options, they would not be liable to ensure water quality from an extreme rain event, but when NBS and other surface solutions are implemented to percolate and lead rain water directly to the sea, the municipality is required to ensure high water quality. The challenge is finding the best approach to ensure quarter quality in accordance with the WFD, while accepting that smart solutions to filter and ensure water quality from NBS in CCA/DDR can only be developed over time. The Cloudburst Plan was explicitly prepared without having all solutions developed. A lot of future solutions are dependent on business developments.

Regulation introduced retroactively - New legislation has been introduced in Denmark from January 2021, requiring municipalities to carry out socio-economic analysis for handling climate impacts. The legislation requires that socio-economic analyses are made for individual catchment areas and not at city level, despite the legal requirement to ensure an equal level of protection across a municipality. Although this pushes municipalities who have not yet started socio-economic assessments of adaptation plans, the regulation places Copenhagen Municipality in a difficult position. The law is implemented retroactively, meaning the municipality can be forced to conduct new socio-economic analyses at catchment level before being allowed to continue implementing adaptation measures. Such analyses could potentially lead to different service levels, outdating the implementation that started in 2015 and risking delays to the remainder part of the investment plan. Investments of billion euros are at stake at the moment.

Identifying operational costs - separating operational costs of NBS for CCA/DRR compared to NBS for recreational purposes is non-trivial, as NBS are multi-functional, but departments of municipalities are responsible for the different purposes of the NBS have separate budgets.
Rainwater separation and lack of solidarity - Rainwater separation on individual household plots is today required to be privately paid when the municipality decides to separate rainwater from the sewage system. This can be a cost of between 20.000-40.000kr per household (EUR 2.700 - 5.400) and can cause

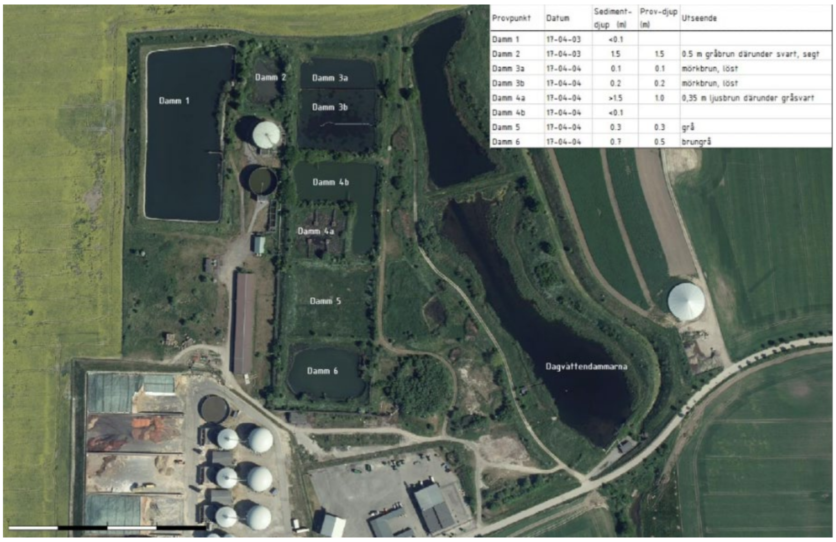
very high levels of conflicts. This should be carried in solidarity rather than on the shoulders of individual household owners.

Limitations to elements included in assessment - Assumptions in the socio-economic analysis have limitations, by not including the non-market values of NBS including the value of increasing urban green areas, improve biodiversity and recreation opportunities, despite these being aspects demanded by citizens and politicians. The reason why this was not included in the Cloudburst plan was to avoid potential criticism of difficult to assess values. Also, these values are not included in guidance of socio-economic assessments of public investments made by the Ministry of Finance. The Municipality would prefer to include these values to obtain a more correct assessment.

<u>Success factors</u> - *Insurance value* - The implementation of the cloudburst plan on neighbourhood level protects households against a 1:100 extreme rain event. This collective investment, paid by residents via the utility bills and municipal taxes represents an insurance value that could be used to decrease individual insurance costs of households, or at a more generic level to avoid an increase in the re-insurance costs for insurance companies. This can also stabilize property values and improve opportunities for investing in Copenhagen. This is going to be a competition factor.
Data availability - Another element considered a success factor was sufficient data available for conducting the socio-economic and cost-effectiveness analyses. Also, the municipality could prove that the flood events they had analysed could material, qua the extreme event in 2011.

Name of case: Tullstorpsån, Sweden

Country: Sweden.
Contact person: Christoffer Bonthron (Tullstorpsån Ekonomisk Förening).
Climate impacts: Drought, flooding.



Brief about the case: In recent years, Swedish agriculture has experienced extreme wet and dry seasons. To counter the problems of drought and associated crop losses, the Tullstorpsån 2.0 project aims to store water in multifunctional wetlands when there is excess water and to 'harvest' it from storage and use it in a recirculating irrigation system.

Photo: Kartor.eniro.se & Tulltorpsån Ekonomisk Förening

The Tullstorpsån is a 30 km long stream where landowners, organised as the Tullstorpsån Economic Association, have worked since 2009 to restore the watercourse in a holistic way to improve biodiversity and water quality (Tullstorpsån 1.0). Between 2009 and 2019, 39 wetlands covering 169 ha and 10 km of the stream were restored. Another 3-4 years of restoration work are left in this first-generation project. Tulltorpsån is the single largest project in Sweden encompassing a total of 100 local projects in a single area.
Having experienced severe dry and wet conditions in recent years, landowners in the Tullstorpsån 1.0 project expanded the collaboration towards climate proofing local agriculture using NBS. This is carried out in Tullstorpsån 2.0, operating from 2019 to 2025. Even if the main purpose of Tulltorpsån 1.0 was to improve water quality and biodiversity, the NBS measures in place have also proven to have a significant impact on reducing flood risks on agricultural land.

Role of Adaptation / DRR: Main objectives of Tulltorpsån 2.0 are related to adaptation of climate change – securing agriculture against drought in spring summer and against flooding in winter months. Additional objectives include improving water quality and biodiversity.

NBS measures implemented: During Tulltorpsån 1.0, NBS measures put in place include river meandering and wetland restoration/construction at large-scale. Today, 50 wetlands and 25 km river have been restored. The project is the single largest NBS project in Sweden receiving the most funding to date. The catchment measures 6,300 km^2. The construction of wetlands and 2 stage ditches has reduced the average peak flow from $12m^3$/sec in 2009 to less than $5m^3$/sec during 2019 and 2020. Where flooding of fields was normal around bottle necks on the river (e.g., bridges), this has now not happened at all during the past two winters. Also, the sediment arriving in the 2-stage ditches is recuperated and placed on low areas on fields, also there improving on the farmability of the land and reducing risk of water amassing. Because of the two-stage ditches, the outlets of the drainage are now not in the river, which before has frequently let to backloading of water to the fields, this has now stopped.

Three NBS measures are planned implemented in Tulltorpsån 2.0: i) **Multifunctional wetland** – using existing ponds to store water from the Tulltorpsån in autumn/winter months for use in spring and summer, where dry spells and droughts occur more and more. The added value is that N and P, high in winter months, is pumped to the ponds and recirculated in summer; ii) **Recirculated irrigation** from the ponds under a) to agricultural fields. Traditional crops start suffering from lack of water in the growing season. Also irrigation would allow for expanding the area suitable for vegetable farming – a priority in Sweden to increase the level of self-sufficiency. Plans are to irrigate half of the farms' 1000ha; and iii) **Customised drainage system** enabling the soil to take both natural rain and recirculated irrigation at the same time (Assessments: detailed pre-study).

Although the 3 NBS measures can exist individually, the combination of the three is expected to provide the optimal pay off for the environment and agricultural production.

Today, traditional crops (e.g., sugar beets) are grown on the 1000ha, and they require irrigation to grow optimally. The long-term idea is to begin production of vegetables to supplement the overused agricultural land used for vegetable production, also contributing towards Sweden's self-sufficiency of vegetables.

Type of NBS assessment implemented:

Technical/physical impacts - *Customised drainage system:* a pre-study of technical feasibility and effectiveness has been carried out on the customised drainage system in collaboration with the Swedish Agricultural University (SLU) and a consultancy, both specialists in drainage. The funder (NEFCO) requires a two-Step approach starting with the pre-study before deciding to move further on to the detailed technical study and implementation.

Recirculated Irrigation: pre-study is underway, identifying the most appropriate irrigation techniques.

Multifunctional wetlands: Idea design is complete. Next Step is to make a technical feasibility assessment and to start implementation. This is quite easy as old infrastructure is already in place. The water ponds are in green field development extremely costly infrastructure (capacity of 100,000 - 200,000 m^3 water), that is already in place, lowering costs significantly.

Economic impacts - Tulltorpsån 1.0 carried out an ecosystem service assessment in 2017. 7 different services out of 15 were monetarily evaluated: biodiversity, water regulation, nutrient retention, recreation, and tourism. Results of the Cost Benefit Analysis indicate that implementation costs totalled 6.4 million EUR while societal benefits amount to 24.5 million EUR, indicating a clear societal gain of the project. Monetary assessment methods included alternative costs, reduced damage costs on housing and yield, willingness to pay for recreational fishing, spatially dependent unit recreation values and tourism expenditures.

Tulltorpsån 2.0 aims to assess the impacts of the combined projects in terms of increased yield assessment and economic impact of the measures along with the potential for crop diversification towards vegetable farming.

Environmental impacts - Tulltorpsån 1.0 assesses nitrogen, phosphorous contents and biodiversity impacts of NBS measures ex post as well as water flow at the river mouth.

An ecosystem services assessment was carried out in 2017, assessing 15 different regulating, provisioning and cultural ecosystem services.

Tulltorpsån 2.0 will assess NBS effectiveness to control drought and flood.

Other assessments - Assessments to investigate the success of the Tulltorpsån 1.0 include: i) an evaluation of why the renaturing of the Tulltorpsån and another four large-scale projects have proven successful. This was an evaluation carried out by the National Sea and Water Agency; ii) a method description and evaluation, investigated by Lund University, investigating the success factors regarding the methods; iii) a fourth major evaluation report is underway to evaluate the success factors and lessons learned of the whole project.

Purpose of NBS assessment: *Recirculated irrigation*: "Identifying adaptation options" was the main entry Step of the technical assessment in the adaptation cycle. *Multipurpose wetland and customized drainage:* "Monitoring and evaluation" was the main entry Step of the technical assessment in the adaptation cycle. Besides CCA, the assessments included following additional purposes: i) water management; and ii) biodiversity enhancement. Following aspects were considered as secondary/indirect purposes of the assessment: the *multifunctional wetland* could become a large area for recreation, bird watchers and hunting. Access is already ensured to the ponds with bird watchers already there. The project includes planting trees both for birds and creating shadow to decrease evapotranspiration of the pond.

Drivers of assessment (reason for choosing the method): The assessment methods applied in Tulltorpsån 1.0 and 2.0 vary, but common for them is a desire to understand the feasibility and effectiveness of the NBS measures for project partners. Also external funding bodies have either requested assessments or undertaken comparative assessments of the Tulltorpsån compare to other national large-scale projects to better understand success factors and lessons learned.

Use of assessment outputs: There are 3 major evaluation reports and a number of smaller evaluations and investigations: i) The ecosystem service report was interesting for the farmers to see the CBA situation and also for funders to assess whether the project funding is well spent; ii) the report from the National Sea and Water Agency was to understand success factors of large-scale projects; and iii) the method report was based on own interest to review methods of why the project is successful and what obstacles have occurred over time.
The 4th major report will be a total evaluation of Tulltorpsån 1.0 on success factors and lessons learned, highlights for municipality and for the region and the country why this was so successful and what could be done for the stakeholders. This report is a requirement from the county board with funding made available for the evaluation of the project, The evaluation will be conducted by external universities.
The type of output and methods applied are a result of the funder requirements, farmer community and wider stakeholders involved in the project. For instance, farmers are very interested in quantitative measures of effectiveness and impacts (e.g., total N and P, the cost-benefit analysis). As choice of method is such an important part of the project, it was also decided to evaluate specifically the different methods and the constraints involved, in addition to assessment of effectiveness. The project was not limited by means or funding to conduct the assessments. They have made adjustment of approaches to save on costs, but not on ambition of evaluation, e.g., by stop paying a consultancy company to carry out weekly water sampling, they trained a local farmer to do the same activity (who has done this for 7 years now).
The output has been used for internal reasons and to disseminate the project in Sweden.

Funding and budget: Funding for the multifunctional wetland and recirculated irrigation is part of autonomous adaptation efforts of one individual farmer, interested in adapting to drought and flood risks in the future.
The multifunctional wetland is based on the existing of natural and artificial water ponds that would be recovered to store water in large scale. As then new Rural Development Programme from 2023 can provide potential funding for water magazines and specialised drainage systems, the project hopes to obtain funding for the multifunctional wetland NBS. At the moment, the project takes one pond per year.
The adjustable drainage system NBS has received funding from NEFCO and WWF.

Provisions/structures in place for carrying out long-term assessments: *Customised drainage***:** part of the pre-study is to describe what kind of evaluation and assessment system will be built in parallel with the implementation of the drainage system. This will be carried out by SLU.
Recirculated irrigation and multi-functional wetlands: no long-term assessments have been decided upon yet, but the project partners are in discussions on securing funding to enable SLU to undertake assessments on several strands, e.g., how much P and N can you take from the river to the ponds and fields and what are the impacts on agricultural productivity from recirculated irrigation compared to no irrigation.

Vulnerability and stakeholder involvement: The economic association consists of 90 farmers and also people living in the villages close to the river, a total of 500 people are members. A lot of the people enjoy the recreational opportunities of the project.
Annual major meetings take place for all along with different events, social media, newsletters and website.
Daily challenge to combine different interests. Ambition to provide a hiking path along the entire river from the sea over the 30 km. The problem with some land owners is that they don’t want people on the fields with horses. Others are interested in hunting, and don’t want people to come in and out of the area. Not reached ambition. As a consequence, the pathway is broken up and implemented where possible.

In the beginning activities were funded 100% by external funding, later on, only 75% were external project funding, but the association was able to cover the remaining 25% with funding from the rural development programme, having several projects running simultaneous to cover the needed funding.
In the beginning, not all were positive of the project, but now seeing the effect on flood protection, biodiversity and water quality. Several farmers where no physical actions done, and now they want it on their land, but unfortunately Tollturspsån 1.0 is closing down. Last wetland is being made now.
When the Tulltorpsån 2.0 idea was proposed to the farmers in the association in 2019, with the 2018 drought event in fresh memory, all farmers wanted to have the measures implemented on their property.

Barriers & success factors for the NBS assessments:
Barriers -The largest barrier is the economy, although the project obtained all the funding it needed.
The amount of efforts to obtain funding and to report on activities costs a lot of time and effort. Convincing farmers of the idea of NBS to leave a part of their land for wetland and remeandering of the river was not easy in the beginning, but as farmers could see the impacts of the projects, they are all interested in having NBS implemented on their land. The lessons from the project can help farmers in other areas and projects to replicate the way of involving farmers and obtaining accept.
Farmers need a long-term perspective in a project, which requires dedicated project manager and accountant in the association.
In the beginning, the project did not get the support from the municipality. The funding system was not open for the economic association. Some people on the county administrative board found it so successful and interesting that they opened the programme for economic association to apply for funding.
Success factors - The project started with a few farmers who started to discuss how to improve water quality and over time organized themselves in the economic association that to day covers the entire catchment. The project is managed locally by a professional project manager and they have managed to get all land owners along the river to opt in the project (Tulltorpsån 1.0) and all farmers were interested in partaking in Tulltorpsån 2.0).
The project has worked systematically with documenting and quantifying impacts of NBS and also on investigating methods for assessing NBS. The evidence serves internally to inform farmers and consolidate the emerging understanding of what NBS can do and externally to inspire and inform other projects and regional authorities.
Farmers do not want to invest money and they don't want to get involved in paper work. A dedicated project manager was therefore engaged to take care of external funding, contacts and reporting. Also, farmers need long-term perspectives in a project, hence projects that run over longer time periods with a seamless project management in place.
The response from nature has been very fast, which has helped convince farmers of the win-win possibilities.

Case name: Camargue Saltworks Restoration, France

Country: France.
Contact person: Brigitte Poulin (Tour du Valat Research Institute)
Climate impacts: Coastal erosion, coastal flooding, sea level rise.

Brief about the case: A large restoration project started in 2011 in the former saltworks of Salin-de Giraud, located in the southeast of the Rhône delta, within the Camargue Regional Natural Park and the UNESCO's Man and Biosphere Reserve. This site represents a vast coastal area of 6,500 ha, partially transformed and used for industrial salt production from 1950 to 2008. It was characterised by a strong artificialisation, with seafront dykes and disconnection among different water bodies used as ponds for salt extraction. After the acquisition of the area by the French Coastal Authority (Conservatoire du Littoral; in 2008-2012), a fundamental shift in the vocation of the site from salt production to wetland restoration guided the new management strategy, turning the former saltworks into a buffer zone to mitigate impacts of storms and sea level rise. The main purpose of the project was to restore the natural hydrology, in particular by allowing natural water exchanges among the lagoons part of the wetland and between the wetland and the neighbouring hydro-systems (Rhône River, Vaccarès lagoon and Sea). The decision not to rebuild a collapsing sea-front dike gave an opportunity to restore the coastal dynamics in areas submitted to high erosion. Another dike built in 1859 to protect people and property, located further inland, will be adapted to ensure proper flooding protection in the Rhône delta.
Positive effects have been already detected, from an environmental, social and economic point of view. A protecting natural sandbar is building up behind the collapsed dike. Restoration works have also created a new space for recreational activities and provided opportunity for knowledge development in the field of coastal dynamics and management.

Role of Adaptation / DRR: Main objectives are related to the rehabilitation of natural ecosystems and related services, including in particular habitat and biodiversity conservation. Climate change adaptation and DRR are however important components of the restoration project. The restoration of coastal ecosystems and dynamics contributes to providing a buffer zone to better cope with coastal erosion, coastal flooding and sea level rise. The maintenance and strengthening of the inner dike has important DRR implications, aiming to protect goods and people from flooding.

NBS measures implemented: Restoration of coastal habitats.

Type of NBS assessment implemented: The assessment covered the following main NBS impacts.
<u>Technical/physical impacts</u> - The assessment focused on hydrological aspects and ground elevation (DTM – Digital Terrain Model through Lidar data), also to evaluate alternative interventions and different SLR scenarios. These aspects have been considered during all the phases (ex-ante, operational, and ex-post).

Technical feasibility and effectiveness assessment was based on in-situ measurement (e.g., coastline location, water level, etc.), remote sensing (e.g., evolution of the coastline, sand bar formation), and hydrological modelling to define pathways for natural water flow and needed hydraulics measures as well as evolution of water level and salinity depending upon different management and SLR scenarios. The result of this assessment showed that there is a very variable coastal dynamic in the area; there are places experiencing erosion and others where accretion prevails. According to monitoring, the whole net balance is positive with an increase of habitats (about 9 ha).
<u>Economic impacts</u> - Economic aspects were only partially assessed, mainly focusing on the implication of the possible reconstruction of the seafront dike. Economic aspects have been in particular considered during the ex-ante (qualitatively) and operational (quantitatively) phases.
Costs for re-building the 9 km seafront dike (which collapsed) with reinforcing groynes (13-17 million Euros for the seafront dike + 7-24 million Euros for the groynes + 800,000 €/year for maintenance) were compared with cost for reinforcing the 16 km inner protection (7-13 million Euros + 80,000 – 140,000 €/year for maintenance).

However, a proper evaluation of NBS impacts on economic activities was not performed. Besides cost evaluation and comparison, the decision to not rebuild the seafront dike was mainly based on a **qualitative coast-effectiveness assessment**, which also considered the potential value of the restored wetland ecosystem. From a pure economic perspective, it must be considered that salt production provided jobs and revenues for local communities, which were greater than those provided by current economic activities. The French Littoral Conservatory and the other co-managers of the area aim to support sustainable economic activities (e.g., sustainable tourism, recreational activities, traditional fisheries, traditional waterfowl hunting, electric bike rental, etc.) also to improve socio-economic benefits for the local population. Qualitative evaluation of the effects of the renatulisation project on some specific activities was performed: e.g., these have been considered very good on local, traditional fisheries, while several conflicts shall be solved with hunters.
Environmental impacts - Environmental impacts have been considered during all the phases (ex-ante, operational, and ex-post), focusing on **monitoring** the changes in water flow, water level, salinity, salt-marshes accretion and extension, and distribution of aquatic plants, benthic macroinvertebrates, fish of the lagoons and water birds.

Purpose of NBS assessment: "Identifying adaptation options" has been considered the main entry Step of the assessment in the adaptation cycle, in particular to support the decision to maintain and restore or not the collapsed seafront dike. "Monitoring and evaluation" constitutes the second entry Step for relevance. DRR implications are specifically related to the inner protection dike; main entry Steps of the assessment in the DRM cycle are: (i) planning and implementation of NBS; and (ii) assessments as part of ongoing maintenance and operations.
Besides CCA and DRR, the assessment included following additional purposes: (i) water management, (ii) green space management; specifically "blue" space management (rehabilitation and management of aquatic habitats, such as salt marshes and mud flats); (iii) biodiversity enhancement. Following aspects were considered as secondary/indirect purposes of the assessment:

- Wellbeing; the site is freely open to any people (it is very famous in the Camargue for providing large, open and free natural space). There are several recreational uses of the beach, like kite surfing, bathing, and other coastal and marine sports. Uses have been mapped and plans defined for specific activities.
- New economic opportunities and green jobs; a diagnostic study on current socio-economic activities and future potentiality is available, focusing on small activities providing some income to local communities (traditional fisheries, sustainable tourism, recreational activities).

Drivers of assessment - reason for choosing the method: Major drivers for the assessment were considered: relevance for the overall project objectives, expectations from funding bodies (assessment was required by some of the used funding mechanisms), data and knowledge availability, availability of skills and technical competences. No major constraints have been encountered. Initially, not all expertise was internally available; however missing skills were found promptly.

Use of assessment outputs: The site is located within a regional natural park. The French Coastal Conservancy designated three co-managers of the coastal area: the Regional nature park, the National Society for the Protection of Nature, and the Tour de Valat Research Institute. The most important elements the assessment aim to support are:

- The free evolution of the coastline, involving coastal retreat with the natural formation of a sand bar behind the dike, and use of coastal wetlands behind the sandbar to serve as buffer zone against sea storms effects (erosion and flooding).
- The restoration of natural water flows between the land and the sea across lagoons to provide nursery areas for marine fish and habitats to migratory fish and birds.

Main assessment output include: annual reports, targeted recommendations, data, models (e.g., about coastal and hydraulic processes), videos and newsletters. The site managers are currently working on a dedicated web-site, which will also include assessment results. Communication through social media is quite controversial. It is considered relevant, but also very time consuming and risky (e.g., due to "fake news"). Some of the outputs (e.g., annual reports) provide essential information for pursuing adaptive

management/restoration of the site according to the management plan framework. Some others (e.g., videos) are more targeted to the general public, aiming to raise awareness.
Assessment results have been used for adaptive management during and after the project implementation. Gathered results feed the on-going updating of the management plan of the site. Moreover, the gathered experience in the implementation and assessment phases can be shared and capitalized in other similar areas (coastal wetlands), e.g., through videos, workshops, scientific congresses, brochures, fact sheets.

Funding and budget: The restoration project has benefitted from public funds at EU (Life+, Interreg Mediterranean), national (Water Agency, Ministry of Ecology), and subnational levels (Région Sud, Département Bouches-du-Rhône), as well as from private funds (WWF, Total Foundation, Coca-Cola Foundation, MAVA Foundation).
In 2013 a management plan was developed for the restored and protected area: the plan is currently under revision (it is expected to be reviewed every ten years). The plan sets several objectives and for each objective it defines implementing actions (surveys, hydraulic works, etc.) with associated costs. The plan also foresees assessment/monitoring activities and related costs for each of the objectives. When the first plan was developed, data and knowledge was not available for all aspects; this improved during the implementation phase, thus contributing to the plan refinement also as far as assessment is concerned. The management plan responds to five main orientations: (1) Restore a more natural hydrological functioning of the wetland ecosystem, by connecting the site to the neighbouring hydro-systems (Rhône River, Vaccarès lagoon and Sea); (2) Restore the natural ecosystems characteristic of coastal lagoons and sandy coastlines, including dunes, salt Steppes and saltmarshes; (3) Maintain or increase the carrying capacity for breeding colonial waterbirds; (4) Implement adaptive management to sea-level rise, including controlled coastal retreat in areas affected by erosion; (5) Contribute to sustainable development, including green tourism and recreational activities.
Long-term monitoring/assessments are implemented by the owner (the French Coastal Conservatory) and co-managers of the site, as part of the management plan and according to an adaptive approach. The latter implies that they manage the site adaptively through continuous learning derived from monitored data. The assessment is defined in the management plan; part of the funds is secured, while another part needs to be funded through project proposals. A steering committee has been put in place for the management plan; it includes officials, scientists and other experts. The committee is regularly informed about the progress in the design and implementation of the management plan, including the assessment components (monitoring and survey).

Vulnerability and stakeholder involvement: Stakeholders have been partially involved. The project planning and design was made by the French Coastal Conservancy and the representatives of the three co-managing bodies (Regional nature park, National Society for the Protection of Nature, and Tour du Valat) with limited consultation of elected officials and the local population. The French Coastal Conservancy and the site co-managers are working to significantly improve stakeholder engagement. The new management plan includes several engaging activities to understand people's perception on the performed re-naturalisation works, address remaining critical issues (e.g., related to human uses of the area) and improve communication. In 2020, a survey about how communication and people engagement can be improved was conducted.
In past years, stakeholder involvement was mainly based on sharing of data and available diagnostic studies on hydrology, flora, fauna, and socio-economic potentialities. Traditional users (e.g., fishermen and hunters) were invited to share their knowledge on the site.

Barriers & success factors: During the implementation phase, unexpected incomprehension from the local population was encountered (apart from that linked to loss of economic activities related to salt production, which was expected). Unexpected opposition was due to the perception that the rehabilitation project negatively transformed the ecosystem and its landscape, in particular increasing the risks of sea submersion (i.e. in winter) and letting wetland dry in summer. However, these are exactly the natural dynamic of several Mediterranean coastal wetlands. Due to the intervention, the coast is retreating in some areas, but it is accreting in others; a protecting natural sand bar has been forming behind the collapsed dike, while the naturalised wetland offers a protecting buffer zone.

No major barriers in the assessment have been reported. The French Littoral Conservatory designed a governance scheme involving three other institutions, some also providing the needed political support to the project implementation.

Actually, a clear mandate and objectives and related political support have been indicated as major success factors for the initiative. Extensive communication/consultation, also about assessment results, is considered very important as well, and therefore will be strengthened.

Name of case: Dijle River Restoration, Belgium

Country: Belgium.
Contact person: Francis Turkelboom (Institute for Nature and Forest Research - INBO).
Climate impacts: Flood.

Brief about the case: After a long decision-making process (lasting about 25 years), a plan to implement a technical solution (construction of storm basins) was largely abandoned in favour of a NBS that is based on the restoration of the natural floodplains of the Dijle river to protect the city of Leuven (Belgium) from flooding, while also maintaining habitats and biodiversity in the valley. The implementation of the NBS took 5 years (2000 – 2005). In 2012-2013 a comparative social cost benefit assessment (sCBA) was carried out to evaluate the project against a grey alternative (see also see publication https://link.springer.com/article/10.1007/s13280-021-01548-4).

Role of climate change adaptation (CCA) / disaster risk reduction (DRR): When the project was initiated (2000) the main purpose was DRR, particular flood management. The issue of CCA only recently come up (within the policy agencies responsible for the water management), and current strategies are re-considered (e.g., as 100-year flood events now seem to become 30-years flood events).

NBS measures implemented: floodplain restoration (bring back natural flooding regime, restore alluvial floodplain ecosystem, reconnection rivers with their floodplains).

Type of NBS assessment implemented: 1) environmental impact assessment (EIA) (ex-ante); 2) economic assessment (comparative social cost-benefit (sCBA) assessment, accounting for all costs and benefits which will be affected differently by the grey and green intervention) (ex-post). The sCBA made use of qualitative (interviews, survey with key stakeholders, expert knowledge) and quantitative methods (apply existing models (i.e., Nature Value Explorer), data from existing literature, and a choice experiment). There are many more assessments carried out in the area, focusing mainly on hydrology and biodiversity, as the area is also the 'backyards of the university (of Leuven)'.

Purpose of NBS assessment: environmental impact assessment: planning and implementation of grey infrastructure; sCBA: evaluation of green (in place) vs grey (hypothetical) solutions by assessing multiple benefits (flood control, water quality, carbon sequestration, biodiversity, air quality, recreation and landscape experience) and costs in monetary terms.

Drivers of assessment (reason for choosing the method): 1) EIA: policy driven assessment: they suggested a comparison study in cooperation with the water management agency; 2) sCBA: requested by the forest and nature agency to document Flemish example of NBS; specific assessment type/methods evolved throughout the project (depending on data availability, time, stakeholders and steering committee input/needs).

Use of assessment outputs: demonstration and awareness raising NBS (how nature and water management and other functions can go together; case is used by the Nature and Forest Agency and Water management Agency to showcase a successful NBS example; illustration of the differences in costs of both options (grey/green) and the multiple benefits helped to support the argumentation of the client to use/invest in nature); good illustration of how to improve collaboration/cooperation among different stakeholders in water management.

Funding and budget: the NBS project (i.e., restoring floodplains) was primarily funded by the Flanders environmental agency (i.e., VMM, who is responsible for the water infrastructure); the comparative sCBA was fully funded by INBO (research institute); VMM is measuring/monitoring the river, other organization (e.g., local NGO, INBO) monitor other aspects (e.g., biodiversity) in the valley (which is a Natura2000 site).

Vulnerability and stakeholder involvement: stakeholder involvement (throughout the assessment) was an important part of the comparative sCBA, especially for data collection; stakeholders include major policy representatives, recreationist/tourists, local stakeholders (land owners, municipalities). For data collection, stakeholders were involved by interview, survey (among recreationist) at the start of the assessment. Moreover, a multi-disciplinary expert group (steering committee) was established including experts from various national agencies and research institute. Throughout the 1-year project, there have been 3 meetings with the steering committee to discuss, refine and validate assessment results.

Barriers & success factors: *Challenges*: working in a multi-disciplinary team (to understand each other and bring all different points of view together) which was at the same time also the added value to the project; methodological challenge e.g., lack of data, not everything is measurable, uncertainties, outdated data. *Successes:* policy-driven assessment (clear demand); actuality (recent flooding issues); access to different knowledge and background data.

Case name: Elbe Dyke Relocation (Lenzen)

Country: Germany.
Contact person: Christian Damm, Karlsruher Institut für Technologie (KIT).
Climate impacts: River flooding.

Brief about the case: "In the framework of the large-scale nature conservation project "Lenzener Elbtalaue", a dyke along the river Elbe has been relocated. This [project reconnected a former naturally flooded] area with a diverse floodplain, re-establishing alluvial forests, half-open pasture landscapes and other typical habitats of lowland floodplains. With 420 ha it [was] the biggest application of this type of measure in Germany [at that time]. The project successfully combines flood protection and nature conservation objectives. Since the cutting of the old dyke in 2009, the measure could prove its effectiveness during several high-water events." Source: NWRM http://nwrm.eu/sites/default/files/case_studies_ressources/cs-de-01-elbe-final_version.pdf

Role of Adaptation / DRR: Nature conservation (re-establishing floodplain forest) was the first motivation of the project with flood protection becoming increasingly important after the 2002 Elbe-Flood. At the time when the project was developed climate change and the need for climate change adaptation was not part of the discussion. However, today the implemented dyke relocation is an important contribution to climate change adaptation and disaster risk reduction.

NBS measures implemented: "The specific measures applied include: Construction of a new, 6.1 km long dyke which has been shifted backward up to 1.3 km; Opening of the old, 7.2 km long dyke, situated close to the river, in Sections of 200-500 m length; Planting of 160 ha of alluvial forest, with further 130 ha of succession areas for alluvial forests; Establishment of half-open pasture landscapes on 85 ha; Profiling of 45 ha of flood channels in the area [contained] by the relocated dyke; Implementation of a land [consolidation scheme] in order to make areas available for the project." Source: NWRM http://nwrm.eu/sites/default/files/case_studies_ressources/cs-de-01-elbe-final_version.pdf

Type of NBS assessment implemented:
<u>Technical/physical NBS impact:</u> Before the project, the Biosphere Reserve Middle Elbe conducted an assessment of opportunities and limits of dyke relocation which provided important data. Originally, the main purpose of the project was biodiversity conservation. After a major flood event in 2002 the flood-alleviating role of the dyke relocation became of increasing importance for the project. The project assessment involved also intensive biodiversity monitoring (birds, fish, amphibians, soils and vegetation). Some of the monitoring related to birds and amphibians continues until today. As this was one of the first pilot sites for the implementation of large-scale dike relocation, the Federal Waterways Engineering and Research Institute (Bundesanstalt für Wasserbau) had an interest in particular in the detailed assessments of the effect of dyke relocation on flood reduction. Detailed hydrological modeling (two-dimensional, hydro-dynamic numerical model) was done before (ex-ante) the implementation in order to assess the potential effectiveness of the dyke removal and increase in water retention area on reducing the flood peak upstream and downstream. The effectiveness of the dyke relocation was also monitored in detail after the implementation during subsequent flood events. Depending on the importance of the flood event, the effect of the measure on reducing the peak flow has been calculated (compared to the previous status prior to dyke relocation) (Table 12).

Table 12: Effect of dyke relocation on increasing the floodplain and reducing the peak flow during flood events. Source: NWRM http://nwrm.eu/sites/default/files/case_studies_ressources/cs-de-01-elbe-final_version.pdf.

Recurring flood events (discharge)	Share of the flow taking place in the newly created floodplain	Reduction in peak flow
Every 1-2 years (1500 m^3/s)	8.6%	9.2 cm
Every 3-5 years (2300 m^3/s)	27.5%	28 cm
Every 20-25 years (3250 m^3/s)	36%	38.9 cm

This effect has been observed during flood events occurring after the implementation of the dyke relocation. The reduction of (extreme) flood peaks is locally at least between 25 to 35 cm depending on the flood flow rate. The impact of the measures with regards to flood protection could be directly observed during the extreme flood events in January 2011 and June 2013.

<u>Economic impact:</u> Economic benefits have not been assessed in particular. However, the following benefits could be identified:

- Flood protection (water retention) and reduction of flood risk (e.g. in upstream areas).
- Reduction in the costs of maintaining the old dyke: flood protection up to the level given today was only possible through creating an enlarged floodplain and the restoration of the old dyke would not have been the better alternative.
- Biodiversity benefits: the strategy of local community involvement and participatory planning with focus on the benefits for biodiversity conservation were critical for creating acceptance and support for the project among local stakeholders.
- Nutrient retention effects for nitrogen and phosphorous are reported.
- Benefits for the regional development: The project area got quickly established as a regional tourist attraction along the international Elbe bike trail due to the beauty of the restored landscape. Related to an environmental education centre and the biosphere reserve's visitor centre a sustainable increase of the number of visitors occurred.
- During the construction period there had been some socio-economic effects in terms of local employment and local consumption. For example, thousands of trees used for restoring the floodplains were locally produced in cooperation with local stakeholders.

<u>Human/social/cultural impact:</u>

- Enhanced awareness of local community for local biodiversity and the benefits of ecosystems for flood protection.
- The increase in visitors and tourism enhanced the appreciation of local communities for the landscape.
- Employment in local tourism and related services.

<u>Environmental impact:</u>

- Enhanced biodiversity with value for resident and migratory bird species as well as a number of floodplain related plant communities.
- Floodplains provide nutrient retention in particular during flood events.
- Hydrological restoration of the floodplain area.

Purpose of NBS assessment: The main purpose of the hydrological modeling and assessments were to identify the potential effectiveness of opening the old dyke and the relocation of the new dyke for reducing the peak flow during flood events (Step 3 and 4 of the adaptation cycle related to identifying and assessing adaptation options). During and after the implementation, intensive monitoring of the hydrology and biodiversity were conducted in order to assess the effectiveness of the measures (Step 6 of the adaptation cycle on monitoring and evaluation). With regards to the disaster risk reduction (DRR) cycle the assessments and monitoring relates to: (i) planning and implementation of NBS; (ii) showing clear benefits of the measures for DRR during the flood event; and (iii) as pilot site the experience contributes to assessing DRR mitigation options in similar sites. However, the original starting point for the project was the motivation to implement dyke relocation for habitat restoration and biodiversity conservation.

Besides CCA and DRR, the assessment contributed additional purposes including: (i) benefits for water management related to water quality and nutrient retention, (ii) green space management related to local community involvement and tourism; (iii) biodiversity enhancement through habitat restoration; (v) habitat regeneration through restoration of the riparian habitats and their natural hydrology; (vi) knowledge and social capacity building through community involvement and environmental education; (vii) social justice and social cohesion as the project contributed significantly to local development and income (e.g. tourism) in one of the poorest regions of Germany; (viii) health and wellbeing as the project improved opportunities for recreation; (ix) new economic opportunities and green jobs during and after the implementation of the project (in particular in tourism and environmental education) in an area of Germany with little employment opportunities.

Drivers of assessment (reason for choosing the method): As this was one of the first pilot sites for a dyke relocation in Germany, the Federal Waterways Engineering and Research Institute (Bundesanstalt für Wasserbau) had a particular interest in conducting detailed assessments and monitoring of the effect of dyke relocation on flood reduction. For the biodiversity monitoring typical indicators and habitat characteristics have been assessed and monitored (birds, fish, amphibians, soils and vegetation), being initiated partly by the project supporting agencies (mainly the Federal Agency for Nature Conservation) requesting specific monitoring, partly by the state biosphere reserve's regular and FFH-related monitoring activities.

Use of assessment outputs: The NBS project was a pilot project on dyke relocation for flood mitigation and biodiversity conservation. Hence there was a particular interest from the different agencies involved from local to the federal level and the project had support from the highest political level within the federal state. This was important for moving the project forward. In particular the Federal Waterways Engineering and Research Institute (Bundesanstalt für Wasserbau) had an interest in assessing and demonstrating the effect of dyke relocation on flood reduction. As a follow-up of this successful project there are about 10 similar projects in implementation stage and further projects in a planning stage.

Funding and budget:
1. Construction costs of the new dyke: 11.5 million €.
2. Costs for opening the old dyke: 1.5 million €.
3. Unknown amount for the compensation to farmers for abandoning farmland (444.5 ha) that has been turned into a floodplain.

"The new dyke has been financed by the Land Brandenburg, supported by national and European means (funding from the German Joint Task program of the Federal government and the federal States for the improvement of the agrarian structures and coast protection; GAK). [The opening of the old dyke as well as the restoration measures have been 75% financed by the German government from a federal budget for "large-scale conservation projects" with 18 % contribution by the State of Brandenburg.] The remaining 7% came from the [project executing] organization Burg Lenzen e.V., in alliance with different nature conservation NGOs. […] Thanks to the multifunctionality of the measures applied (nature conservation, flood protection), [a combination of different financial resources was possible]. Furthermore, to benefit from all financing sources, a private body was needed as applicant, and an association (Trägerverbund Burg Lenzen e.V.) has been created with different stakeholders for this purpose." Source: NWRM http://nwrm.eu/sites/default/files/case_studies_ressources/cs-de-01-elbe-final_version.pdf

Vulnerability and stakeholder involvement: Local stakeholders include local farmers (mainly one large-scale holding company that evolved from a former GDR enterprise ("LPG")), municipality, mayor, local stakeholders involved in tourism (private accommodation and hotels). They were consulted and involved before and after the implementation.

Barriers & success factors: *Barriers:* "Reflections on a dyke relocation for purely hydraulic reasons had started in the 1960s but had not been further followed up mainly due to financial reasons as well as the frontier status of the area (between Eastern and Western Germany). The issues of hunting and fishing as well as the accessibility of the area had been the main controversial issues coming up in the public participation process but they could be solved to a large extent. Financing had been a problem at some point, but could be resolved."

Source: NWRM http://nwrm.eu/sites/default/files/case_studies_ressources/cs-de-01-elbe-final_version.pdf

Factors of success: As pilot the project had the political support up to the highest level within the federal state. This helped to ensure the support from public agencies as well as some local stakeholders.

Stakeholder consultations and facilitation at the beginning about the value of dyke relocation for flood mitigation and nature conservation helped to gain support among local stakeholders. After implementation the benefits (flood mitigation, conservation and an increase in tourism) were well perceived and helped increasing the acceptability notably. “The project shows a successful combination of nature conservation, flood protection and other objectives (agricultural, regional development, and others). The continuous [efforts on persuasion of a few local players over several years] is highlighted as one key factor for the successful implementation of the project. The prior implementation of research projects ensured the effectiveness of the measure design, but was also very useful for providing support for public discussion. The measures are suitable to be applied also elsewhere. However, areas [largely] free of settlement are needed.” Source: NWRM http://nwrm.eu/sites/default/files/case_studies_ressources/cs-de-01-elbe-final_version.pdf

Name of case: Green roofs: Combining mitigation and adaptation measures

Country: Switzerland.
Contact person: Stephan Brenneisen (Institute for Environment and Natural Resources Zurich University of Applied Sciences ZHAW).
Climate impacts: Storm water management, energy savings.

Brief about the case: The Green Roof (GR) programme started in 1996 with a campaign, including financial support, for GRs on flat roofs in Basel. The campaign was motivated by energy savings, although other benefits, e.g., storm water management was also recognized. The campaign lead to the establishment of approximately 80.000m2 of GRs. A couple of years later, a second campaign with co-funding was made available.

Photo: Stephan Brenneisen

In 2000, GRs became part of the building code, making GRs mandatory on flat roofs in Basel, and today GR requirements also apply in relation to retrofitting of flat roofs. GRs are no longer supported financially. In 2006, around 23% of flat roofs in Basel were green, today the share is estimated to have increased to around 40%. It is expected that the city will gain renewed interest in GR as a climate adaptation measure.

Role of climate change adaptation (CCA) / DRR: The main purpose of the project was not specifically CCA/DRR, but storm water management and energy savings.

NBS measures implemented: Green roofs.

Type of NBS assessment implemented:
Technical/physical NBS impact assessments: In 2007 an inventory was made of the number/extent of GRs in Basel. It is hoped, that city authorities can be convinced to update the inventory, perhaps even make updates mandatory. There has not been any studies on the effects of the roofs on storm water mitigation.
Economic impact: Following the 1st GR campaign it was estimated that the 1 million Swiss Franc made available to support private installation of GRs released 9 million Swiss Francs of private investments, and lead to the establishment of 120 GRs (around 80.000m^2). An assessment was also made by the city of how much energy was saved from the measure.
Environmental impact: Long term monitoring of species living on green roofs in Basel. Monitoring based on ex-post (after the GRs are established) and on-going in-situ measurements related to quantitative indicators (species), accounting for spatial and temporal variation. Indicator species are snails, butterflies, beetles, grasshoppers, spiders. The assessment has revealed a fair share of red-listed species present on the roofs. In total 25 roofs are monitored, varying in size, substrate depth, direction etc. The monitoring has taken place since 2013, and is performed every two weeks in the period April-October. No modelling is performed.

Purpose of NBS assessment: Assess the benefit of GRs for biodiversity and investigate how different factors affect the benefits (e.g.,size, substrate thickness).

Drivers of assessment (reason for choosing the method): Primary driver was scientific interest and knowledge (personal). Ideal situation: money, knowledge, time and people were available.

Use of assessment outputs: Results used for scientific publications and reports aimed at collegial exchange of knowledge and at providing input for planners and architects. Videos have also been created, e.g., showing how to implement monitoring in practice, thereby allowing others to replicate the methods and creating a basis for conducting comparative analyses. Results also used as input to building code, and for establishing a framework that can be used by other cantons. The interview person is a member of the Swiss norm committee on GRs; once the long term monitoring data has been analysed in full, he expects it will provide sufficient proof of the benefit of GRs for biodiversity such that GRs become included in the building code for flat buildings in all of Switzerland. In 2005 the first World Conference on GRs were held in Basel, showing what had been done; another World Conference on GRs is planned to be held in Basel in 2024. Dialogue with industry on how to make it as easy and good as possible; industry tends to complicate. Excursions arranged where people can come and see GRs with their own eyes; makes it easier to understand the idea behind GRs and which factors should be considered when establishing GRs.

Funding and budget: The funding for the two GR campaigns came from an energy fund in Basel. 5% of energy bills go to this fund, which purpose is to support measures of energy savings. Initial monitoring of species in GRs was also financed by this fund. Since GRs have become part of the building code, funding from the fund has ceased. The city pays for consulting services and development of guidelines related to the establishment of GRs. Funding for the ongoing monitoring of biodiversity on GRs is provided by the Federal Ministry of Environment.

Provisions/structures in place for carrying out long-term assessments: Monitoring has taken place since 2013 and continues until 2023; the Federal Ministry of Environment finances this long term monitoring.

Vulnerability and stakeholder involvement: Permissions for making assessments, e.g., in relation to access to GRs, are required, but they are granted via standard procedures. Otherwise no real involvement of stakeholders. Good cooperation with the city.

Barriers & success factors for the NBS assessments: *Barriers:* Since GR requirements have become part of the building code in Basel, in many cases the establishment/design tends to follow the specified minimum requirements rather that focus on optimising the design. When making excursions to GRs it is always the same people that comes (i.e. those interested in nature) – challenge to attract other relevant stakeholders. *Success factors:* Money, knowledge, time and people for making the assessments.

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