Nordic Council of Ministers

WORKING WITH NATURE-BASED SOLUTIONS

Synthesis and mapping of status in the Nordics

Authors

Leonard Sandin[1], Isabel Seifert-Dähnn[1], Ingvild Skumlien Furuseth[1], Annette Baattrup-Pedersen[2], Dominik Zak[2], Johanna Alkan Olsson[3], Helena Hanson[3], Samaneh Sadat Nickayin[4], Maria Wilke[4], Matti Koivula[5], Marika Rastas[5], Caroline Enge[1], Kristina Øie Kvile[1], Lisa Lorentzi Wall[3], Carl Christian Hoffmann[2], and Rúna Þrastardóttir[4]

[1] Norwegian Institute for Water Research (NIVA)
[2] Aarhus University (AU)
[3] Lund University (LU)
[4] Agricultural University of Iceland (AUI)
[5] Natural Resource Institute Finland (Luke)

Suggested citation

Sandin, L., Seifert-Dähnn, I., Furuseth, I.S., Baattrup-Pedersen, A., Zak, D., Alkan Olsson, J., Hanson, H., Sadat Nickayin, S., Wilke, M., Koivula, M., Rastas, M., Enge, C., Øie Kvile, K., Lorentzi Wall, L., Hoffmann, C.C. and Þrastardóttir, R. (2022). Working with Nature-Based Solutions. Synthesis and mapping of status in the Nordics. Nordic Council of Ministers. Denmark: Copenhagen.

Resume

The world is currently facing a biodiversity and climate crisis which are globally interlinked. Nature-based solutions (NBS), defined as "actions to protect, sustainably manage, and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously benefiting people and nature" is part of the solution to these challenges. Here we give a status overview of nature-based solutions in the Nordic countries, obtained within the S-ITUATION project[1] focusing on 1) what is the current status of research on NBS in the Nordic countries? 2) what policy framework(s) exist for NBS in the Nordic countries? 3) what challenges do Nordic countries experience in the process of mainstreaming NBS? 4) what key examples of projects implementing NBS exist in the Nordic countries? We have done this using several approaches: 1) a review of the academic literature, providing insights on the status of research on NBS in the Nordic countries; 2) a grey literature review in each Nordic country, to describe the policy framework for NBS and practical implementation of NBS projects across the Nordic countries; 3) compilation of a Nordic NBS case projects catalogue, which contains implemented case projects from each Nordic country, using NBS in all major ecosystems: terrestrial (forests and agricultural land), freshwater, coastal and marine, to show the breadth of NBS used in the Nordic countries, 4) Nordic NBS stakeholder consultations.

Research on NBS across the Nordics includes several research initiatives. Currently the most central research initiatives are the Nordic Council of Ministers programme on NBS, which is a focused four-year programme. Many Nordic universities and research institutes are also involved in different research projects focusing on or including NBS and there is an exponential interest from researchers in this area. Most of these research projects are targeting NBS in urban areas. In a structured peer-review of scientific publications using the term 'nature-based solutions', 64 research papers were found related to the Nordic countries. These studies varied from large-scale ecosystem-based approaches to small-scale NBS. Most of the studies assessed the NBS functions in relation to biophysical qualities, such as water retention capacity, flood risk reduction, health benefits and biodiversity contribution, but there were also studies focusing on potential economic benefits from NBS. Regarding policy frameworks it is evident that these are at different stages of development when it comes to mainstreaming the concept of NBS into policy across the Nordics. Norway and Sweden have adopted the term to a larger degree than Denmark, Finland and Iceland. Still, all five countries conserve, restore and work actively on developing sustainable use of nature, but use other terms (e.g., 'blue-green infrastructures or solutions', 'restoration', or 'ecosystem services') in their policies and guidelines.

NBS governance and implementation is an area that is currently advancing rapidly. At the same time, there are still several challenges as well as also opportunities for using NBS to mitigate and adapt to climate change, protect biodiversity and ensure

1. https://nordicsituation.com/, https://www.niva.no/nordicsituation

human well-being. Regarding challenges and gaps, we divide these into 1) natural-scientific and technical knowledge gaps, 2) economic shortcomings, 3) regulatory, governance, and policy challenges, and 4) weak stakeholder collaboration. In the project we have identified 54 key examples of projects implementing NBS in the Nordic countries. Most of these cases were related to freshwater, followed by urban/artificial NBS. The number of implemented NBS projects has increased, especially in the last couple of years. Our key messages and recommendations for future mainstreaming of NBS are: 1) clear political prioritization is needed to mainstream NBS into policy and practice, 2) appropriate institutional structures, procedures and policy instruments at all governance levels are essential to facilitate the implementation of NBS, 3) better funding structures for NBS are needed, 4) we need to develop common standards, long-term monitoring and better cost-benefit evaluations of NBS, and 5) the knowledge base in all phases of NBS projects needs to be strengthened.

Contents

This publication is also available online in a web-accessible version at https://pub.norden.org/temanord2022-562

Foreword

Nature and climate are intrinsically interconnected. Thus, it is of utmost importance to address the climate crisis and the biodiversity crisis together, and to focus on solutions which benefit both climate and biodiversity. Nature-based solutions, which involve protecting, restoring and sustainably managing ecosystems, provide efficient solutions to the negative effects of both anthropogenic drivers on climate change and the loss of biodiversity.

Over the last few years there has been increasing awareness and implementation of nature-based solutions around the world. Reports from the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) and the Intergovernmental Panel on Climate Change (IPCC) see this work as key to achieving global targets for both biodiversity, as well as for climate change mitigation and adaptation.

Nordic Co-Operation's Vision 2030 is to make the Nordic Region the most integrated and sustainable region in the World by 2030. To help reach this goal, The Nordic Council of Ministers (NCM - the official body for inter-governmental co-operation in the Nordic Region) has allocated 26 million DKK to a programme consisting of five projects on nature-based solutions in the Nordic countries. The aim is to further develop and mainstream nature-based solutions for biodiversity and climate change adaptation and mitigation. This involves working with solutions that increase and maintain land and sea-based carbon sinks.

This report aims to synthesize current work and the development of nature-based solutions in a Nordic context. It is the first project (S-ITUATION) in NCM's Nordic nature-based solutions programme. It will provide a platform for information dissemination and further deliveries on how to best take forward work on the conservation and restoration of ecosystems, in order to provide cost-effective mechanisms for achieving these goals. The range of Nordic ecosystems and different categories of nature-based solutions are covered, and knowledge gaps discussed.

When the project to write a synthesis on nature-based solutions in the Nordic region was put out to tender, it was the steering group's wish that the synthesis would contribute to a wide spread of knowledge among relevant partners and professional environments, and to provide better coordination of measures and to increase the cost-benefit ratio. Norwegian Institute for Water Research NIVA (Norway) together with partners from Aarhus University (Denmark), Natural Resources Institute Finland (Luke) (Finland), Agricultural University of Iceland (Iceland), and Lund University (Sweden) won the tender and have now carried out the S-ITUATION project where the current report is one of the main outcomes. This work will form the basis for future projects in the programme dealing with policy development, best practice and guidance for implementation at national level.

Jóna Ólavsdóttir, Programme Coordinator, Nordic Council of Ministers, The Faroese EPA (Umhvørvisstovan), Faroe Islands

Irene Lindblad, Leader of the Steering Group, Senior advisor, Ministry of Climate and Environment, Norway

Anna Planke, Vice Leader of the Steering Group, Ministry of Climate and Environment, Norway

Thanks to the steering committee:

Anki Weibull (The Swedish EPA (Naturvårdsverket), Sweden), Anna Planke (Ministry of Climate and Environment, Norway), Bo Storrank (Ministry of the Environment, Finland), Eva Juul Jensen (The Danish EPA (Miljøstyrelsen), Denmark), Irene Lindblad (Ministry of Climate and Environment, Norway), Kolbrún í Haraldsstovu (The National Museum (Tjóðsavnið), Faroe Islands), Lise Lykke Steffensen (NordGen), Lotta Manninen (Ministry of the Environment, Finland), Marie Karlberg (NMRS) and Salome Hallfreðsdóttir (Ministry of the Environment, Energy and Climate, Iceland).

Thanks also to the reference group:

Elisa Keeling Hemphill (The Norwegian EPA (Miljødirektoratet), Norway), Lennart Wilhelm Moltke Kæmsgaard The Danish EPA (Miljøstyrelsen), (Denmark), Linda Dalen (The Norwegian EPA (Miljødirektoratet) Norway), Marit Finnland Troite (The Norwegian EPA (Miljødirektoratet) Norway), Oscar Fogelberg (The Government of Åland), Sigga Jacobsen (The Faroese EPA (Umhvørvisstovan), Faroe Islands), and Aaron Tuckey (The Swedish EPA (Naturvårdsverket) Sweden).

Internal quality control of the report was performed by Solrun Figenschau Skjellum, Line Johanne Barkved, Joanna Lynn Kemp, and Nikolai Friberg from the Norwegian Institute for Water Research (NIVA).

Extended summary

The world is currently facing a biodiversity and climate crisis. Climate change is eroding the foundations of our economy, water and food security as well as the health and quality of life, both on a local and global scale. In parallel, the ongoing rapid loss of biodiversity weakens socio-ecological resilience to climate change, and further threatens the well-being of current and future generations. Given the close linkages between climate and biodiversity, it is not surprising that there is an increasing scientific and political awareness of the need for a more integrated approach to tackle these crises with nature-based solutions (NBS). NBS are defined by the IUCN (and as used in this report) as "actions to protect, sustainably manage, and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously benefiting people and nature". In a nutshell, NBS are solutions that make use of nature to solve social, economic and environmental challenges and improve biodiversity. Nature-based solutions are also highlighted by both the IPBES and IPCC as a cost-effective way of meeting the Sustainable Development Goals (SDGs). NBS are win–win strategies for addressing both climate change and biodiversity loss, as well as other societal challenges simultaneously.

In this report, we provide an overview of the status of NBS in the Nordic countries. The report presents the results of the S-ITUATION project (Synthesis - Implementation of nature-based solutions in Nordic countries) funded by the Nordic Council of Ministers' four-year programme on nature-based solutions (NBS). In the report the following questions were addressed:

1. What is the current status of research on NBS in the Nordic countries?
2. What policy framework(s) exist for NBS in the Nordic countries?
3. What challenges do Nordic countries experience in the process of mainstreaming NBS?
4. What key examples of projects implementing NBS exist in the Nordic countries?

Key components of the S-ITUATION project were to review the current status of research on NBS in the Nordic countries, identify which policy framework(s) exist for NBS in Nordic countries, map the challenges Nordic countries experience in the process of mainstreaming NBS, and collect examples of NBS projects in the Nordic countries. This work is based on academic literature, published reports and informal and experience-based knowledge using several approaches, including a review of academic literature, a review of "grey literature" (materials and research produced by organizations outside of the traditional commercial or academic publishing and distribution channels), a compilation of a Nordic NBS case projects catalogue and stakeholder consultations. The work covered the full breadth of Nordic terrestrial and aquatic ecosystems.

The following paragraphs provide a summary of our findings.

1. What is the current status of research on NBS in the Nordic countries?

There are several research initiatives across all Nordic countries, often financed by the Nordic Council of Ministers, which are directly focusing on NBS or having a relevance for NBS. The current, most central research initiatives are: Nordic Council of Ministers programme on NBS which is a DKK 26 million four-year programme (2021–2024) of 5 projects, one of which is this S-ITUATION project and report. The programme also includes NordGen – Conservation of genetic resources for climate adaptation, which is a shared gene bank between the Nordic countries and a knowledge center for genetic resources. NordGen´s mission is to preserve and promote the sustainable use of genetic resources within plants, farm animals and forestry in the Nordic countries, working for a sustainable future.

Many Nordic universities and research institutes are involved in national and international research projects on NBS. Most of these research projects are targeting NBS in urban areas. This is most likely related to EU research funding schemes, which have launched several calls through the EU research and innovation program Horizon 2020, focusing on using NBS to address pressing societal challenges, especially in urban areas. The scientific literature review showed an exponential increase in the number of international publications with a focus on NBS. Out of 912 peer-reviewed publications identified; 64 covered research related to Nordic NBS. These publications were mainly empirical and modelling studies, but also some review studies. The studied NBS varied from large-scale ecosystem-based approaches to small-scale NBS. Most of the studies assessed the NBS functions in relation to biophysical qualities, such as water retention capacity, flood risk reduction, health benefits, biodiversity contribution, as well as some on potential economic benefits of NBS. There were also studies comparing similar types of NBS across different land use contexts.

2. What policy framework(s) exist for NBS in the Nordic countries?

When comparing the Nordic countries, it becomes evident that they are at different stages of mainstreaming the concept of NBS into policy. Norway and Sweden have adopted the term to a larger degree than Denmark, Finland and Iceland. The NBS concept is, in general, not well integrated in the legal structure in most of the Nordic countries. Norway is the only country which has an explicit legal requirement on the use of NBS in some planning guidelines. However, all five countries conserve, restore and work actively on developing sustainable use patterns for nature, and have legislation, strategies and policies that support this, although they use other terms (e.g., 'blue-green infrastructures or solutions', 'restoration', or 'ecosystem services'). Concerning "supportive material" i.e., guidelines or tools, which help practitioners to plan, design and implement NBS, a few examples exist from several Nordic countries, but are often specific to certain types of NBS or certain challenges to be solved.

Regarding financial support, there are in the Nordics some examples of financial support programs, which allow the funding of NBS. These were related to: environmental subsidies for agriculture; public grants for NBS knowledge-building projects for climate change adaptation; direct funding for restoration and nature protection projects; urban climate change adaptation; stormwater treatment; NBS projects for water quality improvement. However, most of these funding opportunities have not been tagged with NBS, but used other terms such as urban green space, green infrastructure, water quality etc. These findings indicate *either* that more programs exist, that would allow the financing of NBS, but which do not explicitly address or consider them as solutions, or that the Nordics, like many other countries/regions are lacking sufficient public and private funding for NBS projects. In this context, we want to highlight the Nordic Council of Ministers' NBS programme, which has the purpose of encouraging the Nordic countries to work together and enhance their knowledge base about NBS. It has funded the implementation of several NBS projects in the Nordic countries.

3. What challenges do Nordic countries experience in the process of mainstreaming NBS?

NBS governance and implementation is an area that is currently advancing rapidly. At the same time, there are still several challenges as well as also opportunities for mainstreaming NBS i.e., making NBS a standard solution and not an exception. The Nordic countries face similar problems to other countries, mainly in relation to 1) natural-scientific and technical knowledge gaps, 2) economic shortcomings, 3) regulatory, governance, and policy challenges, and 4) weak stakeholder collaboration. When it comes to natural-scientific and technical knowledge gaps, we conclude that it is essential to have better evidence of the multiple benefits NBS can deliver across ecosystems and land use types, but also on how local conditions influence their performance. Most attention so far has focused on assessing the environmental aspects and impacts of NBS, without paying enough attention to economic, social and health impacts. More comprehensive assessments are needed, that include evaluations across larger spatial and temporal scales and contain monitoring and evaluation schemes that also comprise participatory planning and governance processes. It is necessary to create an evidence base for the climate zones spanning the Nordic countries, as the transferability of results from other climatic zones or societies is limited. It is also necessary to take into consideration current social, environmental and climate changes, which can undermine the integrity of ecosystems and thus the capacity of NBS to deliver on expected outcomes.

Another challenge for the increased implementation of well-functioning NBS are technical and ecological knowledge gaps of practitioners in the planning, design and implementation of NBS, but also concerning their operation and maintenance. We want to specifically highlight here, that even though it is a fundamental requirement of NBS to have a positive effect on biodiversity, we observe that in many NBS projects, the expected biodiversity benefits are not clearly stated. The consideration of the multiple benefits of NBS, as well as trade-offs between them, makes it difficult to exactly predict the effect or outcome of a NBS and to standardize NBS as can be done with technical solutions. This might undermine the trust in NBS in comparison to engineered and technical solutions. In addition, there is often also a higher competence in technical or engineering solutions in the relevant public agencies, than for NBS, which leads to a preference for these types of solutions (sometimes called "grey" solutions) and inhibits increased adoption of NBS. To overcome this problem of technological path dependency, targeted NBS-education for infrastructure professionals is suggested.

There are several shortcomings in relation to socio-economic aspects of NBS, which are interwoven with other shortcomings. One main issue is the lack of scientific and economic evidence on the costs and benefits of NBS over their complete lifetime. This results in incomplete cost-benefit analysis of NBS, so that NBS interventions cannot properly be compared with alternative solutions. Information gaps arise due to lack of regular monitoring, but also because the observed benefits are not monetized and integrated into economic valuation and accounting methods (i.e., natural capital accounting). This makes it difficult to calculate reliable revenue streams and to develop appropriate investment plans for NBS, which are needed for the acquisition of public as well as private funding.

Governance structures related to NBS differ between the Nordic countries. Due to their multi-functional character, NBS require the development of cross-sectoral structures and policies. Administrative boundaries, sectorization and silo-thinking, as well as a lack of cooperation between private and public organisations, often currently hinders the implementation of good NBS. There is also a need for governance structures that can understand and balance social conflicts between local-level and landscape-level contributions of NBS. Stakeholder collaboration and participation is an important approach to overcome these conflicts.

In a regulatory setting, all Nordic countries would benefit from clear and explicit requirements for when and how the term NBS should be used. This requires a clear definition of what NBS are to avoid greenwashing. Appropriate regulation will create a more stable framework around the long-term development of NBS and ensure that the necessary collaboration between relevant actors is happening.

4. Key examples of projects implementing NBS exist in the Nordic

The S-ITUATION partners collected information on 54 cases of Nordic NBS projects across all Nordic countries and ecosystems. This collection shows that there are already several pilot projects in the Nordics which can inform future projects. However, also some of the previously mentioned challenges are highlighted, such as missing biodiversity targets or lack of regular monitoring.

In conclusion, the multi-functional character of NBS provides a great opportunity to address societal and environmental challenges simultaneously and can bend the curve for biodiversity loss as well as to substantially contribute to climate change adaptation and mitigation. Even though we noticed an increasing uptake of the NBS concept in science, policy and practice over the last decade, there is still room for improvement, to create favourable conditions for NBS in the Nordic countries.

Our key messages and recommendations for future mainstreaming of NBS are:

- Clear political prioritization is needed to mainstream NBS into policy and practice.
- Appropriate institutional structures, procedures and policy instruments at all governance levels are essential to facilitate the implementation of NBS.
- Better funding structures for NBS are needed.
- Common standards and guidelines are needed to support the increased adoption of NBS, including setting clear biodiversity targets.
- Long-term monitoring and more comprehensive cost-benefit evaluation of NBS are required.
- The knowledge base for all phases of NBS projects needs to be strengthened.

For a more detailed description of key messages and recommendations, we refer to chapter 7 of this report.

Norwegian summary

Verden står i dag overfor både en biodiversitetskrise og en klimakrise som er tett koblet til hverandre. Naturbaserte løsninger (forkortes gjerne NBS etter det engelske "nature-based solutions") defineres gjerne som "tiltak for å beskytte, bærekraftig forvalte og gjenopprette naturlige og modifiserte økosystemer, som effektivt og fleksibelt adresserer samfunnsutfordringer, og som samtidig kommer mennesker og natur til gode". Slike tiltak anses som en måte å takle en rekke av utfordringene knyttet til klimaendringer og naturmangfold samtidig. Denne rapporten gir en oversikt over dagens status for kunnskap og bruk av naturbaserte løsninger i Norden, som en del av S-ITUATION-prosjektet. Vi har tatt utgangspunkt i fire forskningsspørsmål:

1. Hva er status for forskning på NBS i Norden i dag?
2. Hvilke retningslinjer og politiske rammer finnes for NBS i de nordiske landene?
3. Hvilke utfordringer opplever nordiske land i prosessen med å ta i bruk NBS?
4. Hvilke eksempler på konkrete NBS-prosjekter finnes i de nordiske landene?

For å finne svar på dette, har vi tatt i bruk flere ulike tilnærminger: 1) en systematisk gjennomgang av faglitteratur for å undersøke hvilken forskning som finnes på NBS i Norden; 2) en systematisk gjennomgang av såkalt «grå litteratur» (rapporter, veiledninger, dokumenter, osv.) i hvert av de nordiske landene for å beskrive de politiske rammene for NBS og praktisk gjennomføring av NBS-prosjekter; 3) vi har utarbeidet en nordisk NBS-prosjektkatalog, som inneholder eksempler på gjennomførte prosjekter som bruker NBS i alle større økosystemer (skog- og jordbruksland, ferskvann, kyst, urbant og hav), for å vise bredden av NBS som brukes i de nordiske landene; og 4) vi har konsultert interessenter som jobber med NBS i Norden.

Funnene våre viser at det finnes flere forskningsinitiativer innen NBS på tvers av de nordiske landene, inkludert Nordisk ministerråds fireårige program for NBS som S-ITUATION er en del av. Mange nordiske universiteter og forskningsinstitutter er også involvert i prosjekter som omhandler NBS, og forskningsinteressen på dette området har de siste årene økt eksponentielt. De fleste av forskningsprosjektene er rettet mot NBS i urbane områder. I litteraturgjennomgangen fant vi 64 relevante forskningsartikler som konkret omhandlet begrepet "naturbaserte løsninger" i Norden. Disse studiene varierer fra økosystembaserte tilnærminger i stor skala til mindre NBS. De fleste av studiene vurderer NBS-enes funksjon ut fra biofysiske funksjoner, som for eksempel kapasitet for vannretensjon, redusert flomrisiko, helsefordeler, eller bidrag til naturmangfold, men det finnes også studier som undersøker de potensielle økonomiske fordelene ved NBS.

Våre undersøkelser av de politiske rammene for NBS viser tydelig variasjon i bruken av selve begrepet «naturbaserte løsninger». Forvaltningen i Norge og Sverige har tatt i bruk begrepet i større grad enn Danmark, Finland og Island. Alle de fem landene jobber aktivt med å bevare, restaurere og utvikle bærekraftig bruk av naturen, men bruker andre begreper (for eksempel «blågrønn infrastruktur eller løsninger», «restaurering» eller «økosystemtjenester») for å beskrive dette i lovgivning, retningslinjer og politisk styring.

Styring og implementering av NBS er et område i rask utvikling. Vi ser fortsatt flere utfordringer, men også muligheter, for å bruke NBS til å redusere og tilpasse oss klimaendringene, beskytte naturmangfold og ivareta samfunnsbehov. Vi har valgt å dele inn utfordringer og barrierer for å ta i bruk NBS i 1) naturvitenskapelige og tekniske kunnskapshull, 2) finansielle utfordringer, 3) politiske, regulatoriske og forvaltningsmessige utfordringer, og 4) svakt samarbeid med interessenter.

I prosjektet har vi identifisert 54 sentrale eksempler på prosjekter som implementerer NBS i de nordiske landene. Denne typen prosjekter har økt i antall, spesielt de siste par årene. De fleste av prosjektene i vår katalog er relatert til ferskvann, etterfulgt av urbane eller konstruerte NBS.

For at naturbaserte løsninger skal kunne tas i bruk og bli en integrert del av fremtidens løsninger for klima og miljø, er det flere praktiske grep som kan tas.

Vi oppsummerer følgende hovedpunkter og anbefalinger for det videre arbeidet med NBS:

- Det er behov for tydelige politiske prioriteringer for å integrere NBS i politikk og praksis.
- Det er avgjørende å tilpasse institusjonelle strukturer, prosedyrer og politiske virkemidler på alle styringsnivåer for å tilrettelegge for implementering av NBS.
- Det trengs bedre strukturer for finansiering av NBS
- Vi må utvikle felles standarder og retningslinjer for å bidra til større opptak av NBS. Dette inkluderer tydelige mål for biologisk mangfold.
- Det er nødvendig med mer langsiktig overvåking og mer omfattende kost-nytte-analyser av NBS.
- Kunnskapsgrunnlaget i alle faser av NBS-prosjekter må styrkes.

For en mer detaljert oversikt over hovedpunkter og anbefalinger viser vi til kapittel 7 i denne rapporten.

Glossary

Conservation - the care and protection of natural resources so that they are available for future generations. It includes maintaining diversity of species, genes, and ecosystems, as well as functions of the environment, such as nutrient cycling.

Drainage – wetland drainage for agricultural purposes uses surface ditches, subsurface permeable pipes, or both, to lower the groundwater depth. Excess water from the plant root zone and underlying soil can enter the pipes through perforations and flow away from the field to a ditch or another outlet.

EEA – European Environment Agency

Eutrophication – a process that increases the generation of biomass in lakes or other water bodies, caused by increasing concentrations of plant nutrients, such as phosphate and nitrate.

Fen – a common peatland ecosystem that typically develops at groundwater discharge sites. Fens are usually dominated by sedges or occasionally by reedbeds, shrubs, and trees. While the groundwater flow path is often the main water source, the hydrology can be much more complex than the simple lateral groundwater flow.

Grey literature - materials and research produced by organizations outside of the traditional commercial or academic publishing and distribution channels. Common grey literature publication types include reports, working papers, government documents, white papers and evaluations.

IPBES – The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services

IPCC – Intergovernmental Panel on Climate Change

IUCN – The International Union for Conservation of Nature

Nature-Based Solutions (NBS) - the IUCN definition of nature-based solutions is "actions to protect, sustainably manage, and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously benefiting people and nature" The United Nations Environment Assembly of the United Nations Environment Programme defines NBS as "actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, resilience and biodiversity benefits".

Nordic countries - the Nordic countries includes the sovereign states of Denmark, Finland, Iceland, Norway and Sweden and the autonomous territories of the Faroe Islands and Greenland; and the autonomous region of Åland.

NPRA – Norwegian Public Road Administration

NVE – Norwegian Water Resources and Energy Directorate

Peat – (also known as turf) consists of decomposed and humified plant litter. The organic matter content is defined to be at least 24% of dry matter (DM) but may also be higher than 90% of DM.

Peatland – terrestrial wetland ecosystems, also named "mires", where waterlogged soil conditions prevent the full decomposition of plant material. The thickness of the peat layer is defined to be at least 0.3 m, but this strict definition does not apply in all European countries.

Restoration – management measures that aim to restore the original form and function of different ecosystem habitats to favourable conservation status.

Rewetting – measures to raise water levels back to the soil surface, to recover anaerobic soil conditions and/or to recover the natural hydrological dynamics/hydraulic connectivity. These processes are important for the growth of natural wetland vegetation, while simultaneously halting carbon emissions from oxidation. Due to subsidence, rewetting of peat soils by closing pumping stations and/or drain systems might also cause inundation.

Sustainable use – methods and rates of resource use that do not lead to the long-term degradation of the environment, thereby maintaining its potential to meet the needs and aspirations of present and future generations.

UNEA – The United Nations Environment Assembly

UNEP – The United Nations Environment Programme

1 Introduction

We are currently facing a biodiversity and climate crisis, which are globally interlinked. On one hand climate change is eroding the foundations of our economy, water and food security, as well as the health and quality of life, both locally and globally. On the other hand, the ongoing loss of biodiversity makes socio-ecological resilience to climate change weak and further threatens the well-being of current and future generations. The World Economic Forum's (WEF) Global Risks Report (McLennan, 2021) concluded that loss of biodiversity and ecosystem collapse will cause "Irreversible consequences for the environment, humankind, and economic activity".

Given the close linkages between climate and biodiversity, it is not surprising that there is an increasing scientific and political awareness of the need for a more integrated approach to tackle these crises using nature-based solutions (NBS) (IUCN, 2020). NBS were defined by the IUCN (and as used in this report) as "actions to protect, sustainably manage, and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously benefiting people and nature" (IUCN 2020, Cohen-Shacham et al., 2016) and as win–win strategies for addressing both climate change and biodiversity loss. In a nutshell, NBS are solutions that use nature to solve social, economic and environmental challenges and to improve biodiversity.

In this report, we will give an overview of the status of nature-based solutions in the Nordic countries, obtained during the S-ITUATION project (Synthesis - Implementation of nature-based solutions in Nordic countries), that was funded by the Nordic Council of Ministers' four-year programme on nature-bases solutions (NBS).

The main aim of this report is to provide a status overview on how Nordic Countries implement NBS. It includes the following research questions:

1. What is the current status of research on NBS in the Nordic countries?
2. What policy framework(s) exist for NBS in the Nordic countries?
3. What challenges do Nordic countries experience in the process of mainstreaming NBS?
4. What are key examples of projects implementing NBS in the Nordic countries?

Nature-based solutions have several definitions (see above). In 2022 the United Nations Environment Assembly (UNEA) defined NBS as "actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, resilience and biodiversity benefits". Nature-based solutions are highlighted by both the IPBES and IPCC as a cost-effective way of meeting the Sustainable Development Goals (SDGs) and they play an essential role in the overall global effort to achieve the SDGs. According to UNEP (2022) they are "effectively and efficiently addressing major social, economic and environmental challenges, such as biodiversity loss, climate change, land degradation, desertification, food security, disaster risks, urban development, water availability, poverty eradication, inequality and unemployment, as well as social development, sustainable economic development, human health and a broad range of ecosystem services". At the same time, there is a growing body of evidence, scientific literature and practitioner experience that there are challenges when it comes to implementing NBS. These include issues such as participation and equity, economic valuation, scale and time effects, integration with built infrastructure plus governance and policy issues (Nelson et al., 2020).

There is a substantial body of international scientific literature and reports on NBS (Arkema et al., 2017; Cohen-Shacham et al., 2019). To complement our understanding of the status of NBS in the Nordic countries, a key part of the project and this report has been to compile information on implemented NBS projects and actions in the Nordic countries. To do this, a synthesis combining scientific and grey literature has been carried out. This covered the breadth of Nordic terrestrial and aquatic ecosystems as well as cost-benefit aspects associated with these. With these insights, we compared results and experiences across the Nordic countries, so that they could serve as a basis for knowledge-sharing, inspiration and the development of future projects on the topic for the Nordic region.

This report is structured into seven main chapters. First, the introduction (chapter 1), then defining nature-based solutions, including uptake of the concept over time (chapter 2), methodology and approaches used in the S-ITUATION project (Figure 1), including a review of the academic literature and grey literature, a compilation of implemented NBS case projects in the Nordics, consultations with Nordic stakeholders, and assessment of knowledge gap and challenges (chapter 3). Chapter 4 presents the results NBS research in the Nordics as well as research activities and research publications focusing on NBS. This includes The Nordic Genetic Resource Center (NordGen), The Crop Wild Relatives (CWR) project, governance conditions for NBS in Nordic countries, societal challenges and ecosystems addressed in policies and publications in Nordic countries, governmental requirements for adopting NBS, support and status provided to facilitate and implement NBS, and examples of NBS projects in Nordic countries. Chapter 5 focuses on the challenges for mainstreaming NBS in Nordic countries, including natural-scientific and technical knowledge gaps, shortcomings of the long-term monitoring of NBS, lack of a clear definition of biodiversity net-gain, the technical and ecological knowledge gaps of practitioners, economic shortcomings, regulatory, governance and policy challenges, and participation gaps. Chapter 6 includes the conclusions from the S-ITUATION project, and chapter 7 offers key messages and recommendations.

Figure 1. The five partners in the S-ITUATION NBS synthesis project funded by the Nordic Council of Ministers.

2 What are nature-based solutions?

2.1. Use of the term NBS in this report

We have focused our work on the term ‘nature-based solutions’ (NBS) and its equivalent in Danish, Finnish, Icelandic, Norwegian, and Swedish, in order to assure a harmonized comparison among countries and ecosystems. We must bear in mind, however, that by limiting ourselves to specific mention of the term nature—based solutions, we may miss out on relevant research, grey literature and implemented cases where the term is not used. Adoption of the term NBS is relatively recent (Nesshöver et al., 2017). It has emerged from the integration of multiple scientific fields (Sowińska-Świerkosz and García, 2022) and the use of the term NBS by international bodies has given a single name to a collection of previously existing and frequently used concepts and practices (such as “ecosystem-based restoration” or “urban green infrastructure”).

The execution and output from the S-ITUATION project, including this report and other products, build on the IUCN global standard for NBS (IUCN, 2020). This standard can be used to assess outcomes and success of NBS in the planning and design phase, as well as during and after implementation. Such a framework is essential to increase the scale and impact of the NBS approach, prevent unanticipated negative outcomes or misuse, and to help funding agencies, policy makers and other stakeholders assess the effectiveness of interventions. Eight criteria are defined in the standard, which are further broken down into several indicators (Figure 2).

These criteria are:

Criterion 1: NBS effectively address societal challenges i.e., the selection process of NBS is according to the societal challenges they are meant to address, and includes their benchmarking and periodical assessment

Criterion 2: The design of NBS is informed by scale i.e., the design of the NBS takes synergies and interactions beyond the intervention site into account

Criterion 3: NBS result in a net gain to biodiversity and ecosystem integrity i.e., these gains need to be clearly defined and measurable

Criterion 4: NBS are economically viable i.e., the economic viability of the NBS are evaluated in terms of the multiple benefits they can bring in comparison to alternative solutions

Criterion 5: NBS are based on inclusive, transparent and empowering governance processes i.e., inclusive, transparent and empowering governance processes are integral to the planning, design, implementation and operational phases of the NBS and include the identification of all intended and unintended consequences, for all affected stakeholder groups and with the aim to “leave no one behind”.

Criterion 6: NBS equitably balance trade-offs between the achievement of their primary goal(s) and the continued provision of multiple benefits i.e., the equitable balance between the trade-offs that arise from the multiple benefits of an NBS interventions to different stakeholder groups is maintained and, if needed, corrective actions to balance these benefits are implemented

Criterion 7: NBS are managed adaptively, based on evidence i.e., adaptive management of the NBS is based on evidence gained by regular monitoring of the intervention throughout its lifecycle

Criterion 8: NBS are sustainable and mainstreamed within an appropriate jurisdictional context i.e., the implementation of NBS should be embedded in the appropriate jurisdictional context and trigger transformative change towards sustainability.

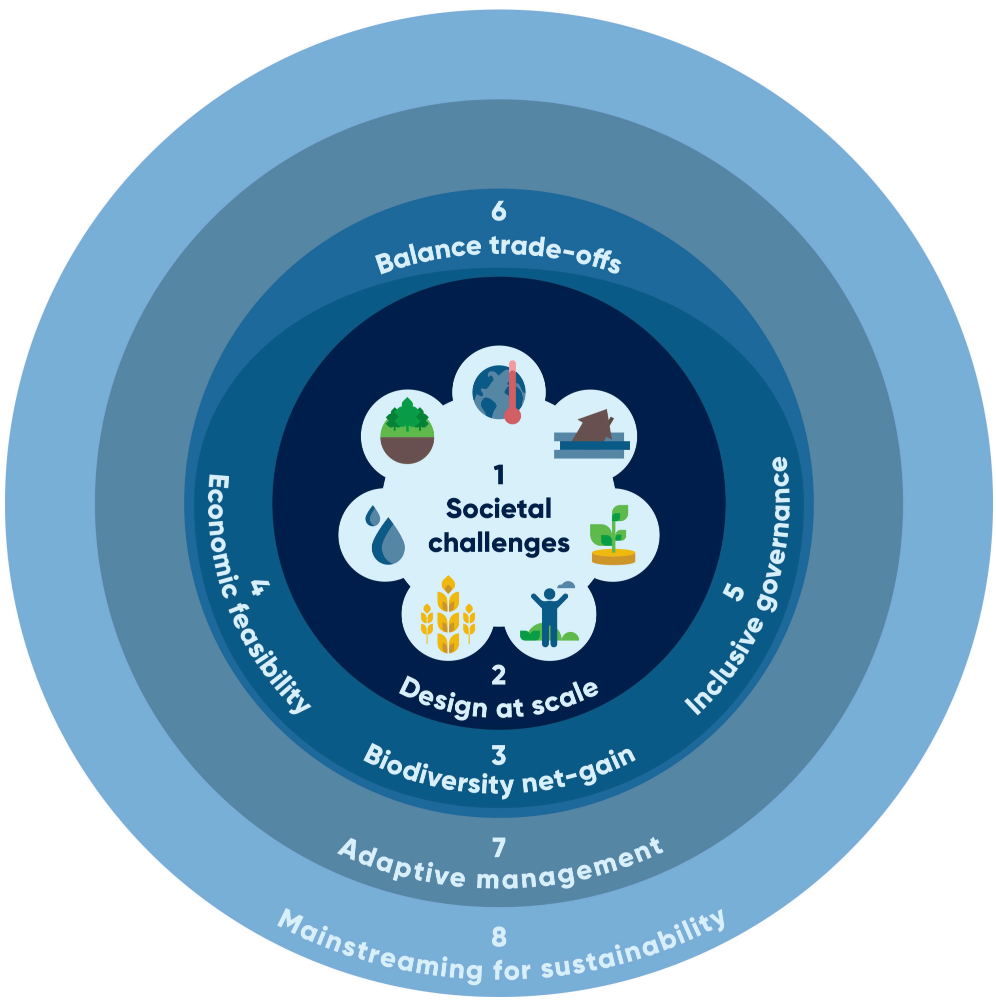

Figure 2. Eight assessment criteria of the IUCN Global Standard for NBS.
Source: IUCN, 2020.

Starting point and uptake of the concept over time

The term 'nature-based solutions' (NBS) was first mentioned in 2008 by the World Bank (2008). This was the starting point for the concept in the international research and policy community (see Figure 3 for a timeline of seminal NBS works). In 2009, the International Union for Conservation of Nature (IUCN) promoted the use of NBS to adapt to climate change, in its position paper on the United Nations Framework Convention on Climate Change COP 15 (IUCN, 2009). Some years later, IUCN adopted NBS as a part of its 2013–2016 Programme (IUCN, 2012) and a definition of NBS was adopted at the world IUCN congress in Hawaii in 2016. NBS is conceptualized as an umbrella term for ecosystem-related approaches, such as *green infrastructure*, *ecosystem-based adaptation* and *ecosystem-based disaster risk reduction* (Cohen-Shacham et al., 2016) using natural features to address societal challenges (Balian et al., 2016). In 2015, NBS was launched as a major research area within the EU research and innovation program Horizon 2020 (European Commission, 2015), which was the entry point for the uptake of the concept on a larger scale in the research community as well as in policy and practice in the EU.

In 2018, the Intergovernmental Panel on Climate Change (IPCC) used the term NBS in their 1.5° C report, in the context of flooding and climate adaptation (IPCC, 2018). In 2019, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) published a global assessment mentioning NBS in relation to the idea that nature can be conserved, restored and used sustainably, while simultaneously meeting other global societal goals (IPBES, 2019). In 2020, the IUCN published a 'Global Standard for Nature-based Solutions', aiming to facilitate the use and uptake of the NBS concept among a diversity of stakeholders (IUCN, 2020). In 2021, the European Environment Agency published a report about NBS in Europe, focusing on policy, knowledge and practice for climate adaptation and disaster risk reduction (EEA, 2021). In March 2022, the United Nations Environment Assembly of the United Nations Environment Programme (UNEA) adopted a resolution about NBS (UNEP, 2022).

Figure 3. Timeline of the publications of seminal works focusing entirely or partly on the nature-based solution concept.

2.2 How is the nature-based concept defined?

There are different definitions of the NBS concept (Figure 4), but the most frequently used, and often referred to in the scientific literature, are the definitions adopted by the IUCN in 2016 (Cohen-Shacham et al., 2016) and the European Commission (European Commission, 2015). In 2022, UNEA adopted the first globally agreed on definition of NBS. This builds on the definition from IUCN and the EC (UNEP, 2022). Our report uses the IUCN definition as a starting point, as this was the commonly agreed definition when the S-ITUATION project was initiated. The definitions share a common ground but do differ. The commonalities relate to the definition of NBS as actions based in nature to address societal challenges and that NBS imitate and enhance natural processes and mechanisms. There is a strong focus on the multifunctional character of the solutions, including benefits for the society, economy and the environment. Nevertheless, most NBS suggests one primary benefit and a series of co-benefits. For example, the main purpose of a protected or restored wetland could be to buffer high floods (water regulation) and the co-benefits could be water purification, increased biodiversity as well as improved recreational values.

The definitions of NBS also have some major differences, which can result in different interpretations of which solutions are categorised or defined as NBS or not. While the IUCN and UNEA more strongly stress the protection, sustainable management, and restoration of existing natural and modified large-scale ecosystems (Cohen-Shacham et al., 2016), the European Commission includes solutions that are "inspired by, supported by or copied from nature" (European Commission, 2015); thereby including artificial solutions such as green walls, green roofs, aquaponics and seawalls (ibid.). All three organisations include the idea that an NBS can provide multiple benefits or be multifunctional, but they link the benefits to different ends. The European Commission links to the three dimensions (social, environmental, and economic) of sustainable development, the IUCN links to human well-being and biodiversity and the UNEP links to all of these benefits.

Figure 4. Central definitions for NBS by the EU, IUCN and UNEP.
Source: NIVA.

3 Methodology and approaches used in S-ITUATION

The focus of the S-ITUATION project was to review the current status of research on NBS in the Nordic countries, identify which policy framework(s) exist for NBS in Nordic countries, to map the challenges Nordic countries experience in the process of mainstreaming NBS and to identify key examples of projects implementing NBS in the Nordic countries. This work is based on academic literature, published reports and informal and experience-based knowledge using several approaches:

1. A review of the academic literature, providing insights on the status of research on NBS in the Nordic countries;
2. A grey literature review (materials and research produced by organizations outside of the traditional commercial or academic publishing and distribution channels) in each Nordic country, to describe the policy framework for NBS and the practical implementation of NBS projects across the Nordic countries;
3. A compilation of a Nordic NBS case projects catalogue, to show the breadth of NBS used. This contains implemented case projects from each Nordic country, using NBS in all major ecosystems: terrestrial (forests and agricultural land), freshwater, coastal, urban, and marine.
4. Nordic NBS stakeholder consultations.

In order to answer these questions, we have: 1) synthesized and extracted information from the existing literature on NBS, 2) mapped projects implementing NBS over time across the Nordics, and 3) given a snapshot in time of the current development of NBS from a Nordic perspective. This does not include all publications, reports, and projects on the topic, but gives a balanced picture of where the Nordics currently are in terms of NBS. The focus of this report is NBS (answering questions 1–3 above) in the five sovereign Nordic states of Denmark, Finland, Iceland, Norway and Sweden, acknowledging the fact that NBS projects have also been carried out in the Faroe Islands and Åland. In the Faroe Islands the first large land-restoration project (the Lendisbati initiative) was initiated in 2022, with the aim to prevent erosion, protect biodiversity and restore wetlands for carbon storage. In Åland, a NBS has been employed to improve four multifunctional wetlands for better water quality, sustainable food production, climate adaptation and increased biodiversity. Both these projects have been funded by the Nordic NBS programme. To our best knowledge no NBS projects have been implemented in Greenland. The methodology applied for each of these approaches are described in detail below.

3.1 Review of the academic literature on NBS in the Nordics

The mapping of scientific literature was performed in order to provide insights on the status of the research and existing scientific publications on NBS in the Nordics. This was done through a structured literature review of peer-reviewed scientific publications (Hart, 1998; Ridley, 2012) that include the term 'nature-based solutions'. We searched for publications in two major scientific literature databases; Web of Science and Scopus using the search string 'nature-based solution*' (with and without hyphen) and included all publications that had been published on this topic including one or several of the Nordic countries from the first use of the term up until June 2021. After removing duplicates, book chapters and conference proceedings, 66 peer-reviewed relevant publications written in English were included in the structured literature review. The results included publications reporting on empirical and modelling studies, and reviews synthesizing results of other studies. The publications were analysed and categorized by: 1) the country of focus in the study (i.e., Denmark, Finland, Iceland, Norway and Sweden), 2) the ecosystem/land cover context (i.e., arable, coastal/marine, forest, freshwater or urban) covered by the study. For both country and land-use type, multiple entries were possible. We also extracted 3) the type(s) of solution (e.g., constructed wetlands, green roofs, parks, agroforestry etc.). The data were analysed both quantitatively and qualitatively (see chapter 4.1 for results).

3.2 Grey literature review

The grey literature review aimed to provide an overview of the implementation of NBS in policy and practice in the Nordic countries. The S-ITUATION partners were asked to undertake a search for grey literature (materials and research produced by organizations outside of the traditional commercial or academic publishing and distribution channels) and policy documents in their respective countries (Denmark, Finland, Iceland, Norway and Sweden). The grey literature review (incl. policy documents) was conducted from December 2021 to July 2022, using the NBS term in five Nordic languages[2] and English. A common set of instructions and templates for a logbook and matrix were created prior to the search to ensure comparability, transparency and replicability. The search included five steps, targeting:

1. The national governments and several national governmental bodies (within environment, agriculture, fisheries, forest, land-use planning and transport) – in the five languages;
2. Up to 15 regional authorities in each country: 5 of these being the regions with the most inhabitants, along with up to 10 randomly chosen regions – in the five languages;
3. Up to 20 local authorities in each country, of which 5 were the municipalities with the most inhabitants, while 15 municipalities were randomly chosen – in the five languages;
4. The main academic institutions (within environment, agriculture, freshwater, coastal/marine, forest, and urban/artificial), and the national academic databases (DK: kb.dk; FI: Finna.fi, Theseus.fi; IS: Skemman.is, NO: CRISTin.no; SE: diva-portal.org) – in the five languages and English;

2. Danish, Finnish, Icelandic, Norwegian ('Bokmål' and 'Nynorsk') and Swedish

5. A common online search engine in each country (e.g., Google, Bing), for which we reviewed the first 50 results or until the results were no longer relevant (whatever came first) – in five languages.[3]

Publications with a clear author/publisher found during this exercise, including the term nature-based solutions or similar terms (e.g., nature-based climate adaptation, nature-based sedimentation pond) were added to a publication matrix for each country. Publications were considered as relevant if they either provided information on how the different Nordic countries are implementing NBS, whether there are programs, regulatory requirements or targeted funding in the Nordic countries for NBS, and if the publications described examples of NBS cases or could support the scientific literature review with relevant research reports. Findings from each country were then summarized by answering the following questions:

1. For what purpose are NBS adopted/suggested? Which societal challenges are they addressing?
2. What ecosystem/land cover are targeted?
3. Do the publications specifically address biodiversity? If yes, how?
4. Are there requirements for adopting NBS? If yes, on which governance levels and for which sectors?
5. What kind of support (e.g., guidelines, scientific reports, financial) is provided to facilitate NBS planning, implementation and maintenance, long-term management and monitoring?
6. What research activities related to NBS have been carried out (national and international projects)?

(See Appendix 9.1: Grey literature search (including policy))

3.3 Compilation of a Nordic NBS implementation case catalogue

S-ITUATION partners identified and collected examples of projects implementing NBS in the Nordic countries using all publicly available sources, i.e., websites, reports and expert knowledge i.e., not only using grey literature as was done above. The project examples were expected to cover all NBS ecosystem types (urban-artificial, forest, agriculture, freshwater, peatlands, and coastal-marine) and NBS categories (conservation, restoration, sustainable use). To qualify as an NBS to be included in the collection, the projects were required to fulfil two minimum requirements, following the NBS definition used in this project and IUCN criteria 1 and 3 (IUCN, 2020):

1. The project must have or at least aim to have a biodiversity net-gain.
2. The project must provide or at least aim to provide another societal benefit (other than biodiversity).

If a NBS project fulfilled these criteria it was added to the project catalogue. Detailed information about the type of NBS, the societal challenge(s) addressed, the biodiversity net-gain, economic viability, monitoring and quantification of benefits was added when available. These data partly represent IUCN criteria 1, 3, 4 and 7

3. Danish, Finnish, Icelandic, Norwegian (Bokmål), Swedish

(see Figure 2), which were identified as most important in a stakeholder consultation exercise and by S-ITUATION researchers.

To get a wider overview of the variety of existing NBS projects, there are several EU-funded research projects or EU-initiatives that have developed quite extensive databases and collected NBS case studies in Europe and globally. However, there are not many case-studies from Nordic Countries in these databases. The highest was 71 cases in the Urban Nature Atlas. All databases listed in Table 1 have search functions, which, for example, allow you to select NBS cases by country or region, for different scales or types of projects. All of these databases were developed before biodiversity benefits were made explicit in the NBS definitions by IUCN and UNEA. Thus, a common weakness is that none of these databases require recordings of such details.

As part of the S-ITUATION project we added Nordic NBS case projects to the Network Nature database.

It is important to note that the Nordic countries fall into three different climate zones: Coastal climate in Åland, Faroe Islands, Denmark, south of Sweden, most of Norway and the southern part of Iceland; inland climate in the middle and north of Sweden, in Finland, and a smaller part of Norway and Arctic climate in Greenland, in the north of Iceland and in the region between Northern Norway and Sweden. These climate zones, along with factors like topography, land-use and -cover and soil type influence the type and need for NBS.

Table 1. Overview of European NBS case study collections (status March 2022)

Project name	Link to NBS case study collection / NBS databases	Geographic coverage	Total cases collected	Cases in Nordic countries
Oppla	https://oppla.eu/case-study-finder	global	327	Ca. 17
Network Nature	https://networknature.eu/network-nature-case-study-finder	global	396	Ca. 16
Urban Nature Atlas (Naturvation project)	https://una.city/	global, focus on cities	1105	71
Natural Water Retention Measures	http://nwrm.eu/list-of-all-case-studies	mainly Europe, focus on water	372	7
Nature-based solutions Initiative	https://casestudies.naturebasedsolutionsinitiative.org/	global	110	0

3.4 Nordic stakeholder consultations

S-ITUATION organized an online workshop which was open for stakeholders from all Nordic countries in November 2021. The focus of the workshop was to learn more on:

- How the concept of NBS is used across different disciplines and ecosystem types in the Nordic region;
- Introduce the IUCN global standard for NBS and discuss its applicability in Nordic Countries and in Nordic ecosystems;
- Uncover implementation barriers and knowledge gaps for NBS;
- Find out how the S-ITUATION project could extract useful and usable knowledge for everyday applications of NBS;
- Give stakeholders an opportunity to exchange experiences with other Nordic stakeholders working with NBS.

Key persons working with NBS in the Nordic countries were identified, where 47 were invited and 27 took part in the workshop, which included people from Denmark, Finland Iceland, Norway, and Sweden. The participants represented national public bodies (11 persons), regional public bodies (3), local public bodies (1), research institutes or universities (10), and consultancies or the private sector (2). Most of the participants worked with freshwater ecosystems (10 persons) or artificial and urban ecosystems (7). Fewer worked with coastal and marine ecosystems (4), forest ecosystem (2), and agriculture (1) and two worked with "other ecosystems".

The workshop was divided into two sessions. The first session focused on the following questions: what would you be interested in learning from other NBS projects, ecosystems, and countries; what outputs of S-ITUATION would be useful for you in your daily work; what are the main knowledge gaps we have regarding nature-based solutions, and what are the largest, most important, or most innovative NBS projects in your country? The second session focused on the IUCN criteria for NBS and participants were divided into groups based on their ecosystem expertise. The questions asked were: What IUCN criteria do you consider as most important or useful for the Nordic Countries or your country and why; what societal challenges related to the use of NBS is your country already good at addressing; and which societal challenges are seldom included or considered in NBS work; what do you consider as barriers to, or facilitators of, the implementation of more NBS in the Nordic Countries and in your country. Where do you perceive the Nordic Countries or your country as having knowledge gaps related to NBS?

3.5 Knowledge gap and challenges assessment

The assessment of knowledge gaps and challenges for mainstreaming NBS in the Nordic countries is based on the review of scientific literature, scanning of the NBS grey literature, information derived in the stakeholder consultations as well as experiences that the consortium members have gained through working with NBS directly or in projects with NBS as a core topic. For the assessment, the following types of gaps and challenges were considered: monitoring routines, definition of biodiversity net-gain, technical and ecological knowledge gaps, economic shortcomings, regulatory, governance and policy challenges and participation gaps.

4 Results

4.1 NBS research in the Nordic Countries

In this chapter we present the results of the answer to the first research question of the project “What is the current status of research on NBS in the Nordic countries?”

4.1.1 Overarching NBS research activities in the Nordics

There are several research initiatives across all Nordic countries, often financed by the Nordic Council of Ministers, which focus directly on NBS or have a relevance for NBS. The most central, current research initiatives are described below.

Nordic Council of Ministers four-year programme on NBS

Nordic Council of Ministers has allocated DKK 26 million to a four-year programme on nature-based solutions. The programme consists of five projects running from 2021 to 2024. These include; 1) a synthesis of nature-based solutions in a Nordic perspective (the S-ITUATION project, on which this report is based), 2) national examples and testing, 3) policy development and guidance for national and regional administrations, 4) guidance and best practice, and 5) NordGen: Conservation of genetic resources for climate adaptation (see below).

The Nordic Genetic Resource Center (NordGen)

The Nordic Genetic Resource Center (NordGen) is a gene bank shared between the Nordic countries and a knowledge center for genetic resources. As an institution under the Nordic Council of Ministers, NordGen´s mission is to preserve and promote the sustainable use of genetic resources within plants, farm animals and forestry in the Nordic countries, working for a sustainable future. NordGen continuously leads and participates in different projects relating to the conservation and sustainable use of genetic resources and the project Crop Wild Relatives (CWR) is one of these projects.[4]

The Crop Wild Relatives (CWR) project

The Crop Wild Relatives (CWR) project was started in 2015 and is currently funded until the year 2024. The work has focused on the conservation of CWR which are wild plant species that are closely related to crops and are of special importance to humans, since CWR are one of several tools needed to address food security and climate change. The goal of the CWR project is to achieve Nordic synergy in the field of CWR conservation and sustainable use, and to facilitate Nordic cooperation and knowledge. The long-term aim of the CWR project is to promote climate- and environmentally friendly Nordic agriculture, and sustainable use of genetic resources

---

4. NordGen - Nordic Genetic Resource Center: https://www.nordgen.org/en/about/

in terrestrial settings (Palmé et al., 2019; Palmé, n.d.a). The first part of the project was to produce a Nordic regional CWR checklist. Today the list contains almost 3.000 different CWR and includes the CWR´s taxon, distribution, the relatedness of wild relatives to the crop and the plant´s use.[5] Out of the CWR in the list, 114 have been prioritized based on socio-economic value of the related crops and potential utilization value of the CWR (Fizgerald et al., 2021; Palmé, n.d.b). A national checklist can be easily made from the Nordic CWR checklist and used for planning (Palmé et al., 2019).

The conservation of CWR itself can be considered as an NBS. In-situ and ex-situ conservation provides a direct biodiversity benefit. It assures that the genetic pool and diversity of endemic wild species can be used in an uncertain future, with a changed climate, to meet societal challenges such as food security. The CWR in the Nordic region are adapted to local climate and conditions and therefore contain adaptions to the challenging conditions of the region (Palmé, n.d.a; Thorbjörnsson and Göransson, n.d.). CWR species can contribute to climate change mitigation as they include traits that can be transferred to allow crops to grow less carbon intensively. CWRs could be used to introduce a trait for nitrogen use efficiency into a crop to allow reduced fertilizer use (Global Crop Diversity Trust, n.d.). However, the opportunity to utilize CWR is decreasing as wild populations are under increasing threat from extinction by e.g., agricultural expansion, overexploitation, pollution and extractive industries. With each extinction or population decline, the overall genetic diversity of CWRs also decreases (Satori et al., 2022).

To protect the Nordic CWR for the future, it is important to establish in situ conservation of CWR in the Nordic countries. Today no active in situ conservation of CWR is taking place in the Nordic region, but the CWR project team has suggested a few potential in situ conservation sites. These in situ conservation sites would have to optimize the amount of diversity conserved across a minimum number of sites. It is cost efficient to establish genetic reserves within an existing conservation network, as there are already many established conservation areas in the Nordic countries (Palmé et al., 2019). The top three conservation sites that were suggested for each Nordic country are shown in Table 2 (Fizgerald et al., 2019). CWR populations in these sites would need to be monitored at regular intervals and have suitable management practices to ensure viability and health of the targeted populations (Palmé et al., 2019).

5. The list is available at: https://figshare.com/articles/dataset/The_Nordic_priority_crop_wild_relative_gene_pool_and_distribution_dataset/5688130/3

Table 2. List of the top three conservation sites in the Nordic countries (Denmark, Finland, Iceland, Norway and Sweden) that would be suitable for CWR's conservation (Fitzgerald et al., 2019).

Top three sites	1	2	3
Denmark	Aalborg commune	South Funen Sea & Islands	Roskilde Fjord
Finland	Tornio- and Muonio river area	Hanko and Tammisaari archipelago	Koli National Park
Iceland	Vatnajokulsthjodgardur National Park	Myvatn Laxá region	Vatnsfjordur
Norway	Lista Wetlands system	Sjunkhatten National Park	Trollheimen
Sweden	Mysoxär Tännes	Falsterbo Peninsula & Måkläppen	High coast

Ex situ conservation is the long-term conservation of biological diversity of plants away from their natural habitat. It is most frequently done in seed gene banks, but can also be done in the field, in vitro or by cryopreservation. Traditional *ex situ* conservation should act as back up and complementary measure to *in situ* conservation, and only in rare cases be the main approach for CWR conservation. Several *ex-situ* collections of CWR can be found in the Nordic region (Palmé et al., 2019).

The CWR project also included a study on the effect of climate change on three selected priority CWR species - common hazel (*Corylus avellana* L.), alpine meadow-grass (*Poa alpina* L.) and cloudberry (*Rubus chamaemorus* L.). The results indicated that climate change will influence all three of these CWR species, especially alpine meadow-grass, the species with the most northerly distribution. The effect of climate change on these species must be taken into consideration because if a targeted species is predicted to disappear from an area in the future, *in situ* conservation should not be planned at that location. Furthermore, the populations which are predicted to be adversely affected by climate change should be collected to *ex situ* conservation areas or efforts made to facilitate their migration into suitable areas. More research is needed to find out the effect of climate change on other priority CWR species (Palmé et al., 2019). To develop a proper *in situ* and *ex situ* CWR conservational plan, it is important to develop a national strategy in each Nordic country, in line with relevant international agreements and guidelines and to develop the policy instruments needed to facilitate their conservation and sustainable use, across all relevant sectors (ibid.). In the long term, the CWR project team recommends that a common Nordic approach to CWR should be developed based on international guidelines and strategies, to address the future challenges of climate change and food security. The Nordic cooperation would involve complementary *in situ* conservation sites across the Nordic region, to include different habitat types, in order to be able to encompass the most important CWR species in the region (ibid.).

4.1.2 Examples of large research projects on NBS in Nordic countries

Many Nordic universities and research institutes are involved in different research projects focusing on or including NBS as a term, and there is an exponential interest from researchers in this area. Here we present examples of ongoing and previous research projects from each Nordic country, focusing on NBS (Table 3). Most of the research projects are targeting NBS in urban areas. This is most likely related to EU research funding schemes, including several calls through the EU research and innovation program Horizon 2020, focusing on NBS as a solution to pressing societal challenges, especially in urban areas. Several NBS publications originate (according to the acknowledgements given in the publications) from projects financed through the earlier EU research framework FP7, for example GREEN SURGE and OpenNESS. The FP7 framework focused on ecosystem services and green infrastructure, but as there is a close relationship between these concepts and the NBS concept, it is not surprising that research output funded by the framework includes the NBS term.

Table 3. Key NBS-related research projects from the Nordic Countries (2 examples per country)

Country	Name of project	Focus of the project	Funding agency	Duration	Link to webpage
Denmark	MERLIN	Mainstreaming Ecological Restoration of freshwater-related ecosystems	Horizon 2020	2021–2024	https://project-merlin.eu/
Denmark	Regreen	Regreen promotes urban liveability through fostering NBS in Europe and China	Horizon 2020	2019–2023	https://www.regreen-project.eu/
Finland	DISTDYN	Forestry mimicking natural disturbances	Ministry of agriculture and forestry	2009–2109	https://www.luke.fi/fi/projektit/monimuotoisuuden-ja-puuston-hd
Finland	EVO	Restoration using deadwood and prescribed burning	EU projects SPREAD, EUFIRELAB & RESTORE; Academy of Finland	2001–2051	http://www.metla.fi/hanke/8532/pdf/EVO_methods.pdf
Iceland	RECARE-FP7 (ENV.2013.6.2-4)	Land and river restoration	COST Action ES1306, European Connectivity Research	2013–2018	https://www.recare-hub.eu/recare-project
Iceland	Ecological Restoration	Land restoration	Nordic Council of Ministers	2011–2013	https://www.ecologyandsociety.org/vol18/iss4/art33/
Norway	SPARE	Use NBS in cities to improve biodiversity, recreation and climate change adaptation	The Research Council of Norway	2021–2025	https://www.spare-project.com/
Norway	SABICAS	Develop a user-friendly toolbox that can optimize the use of NBS at catchment scale	The Research Council of Norway	2021–2025	https://www.sabicas.no/

Sweden	Naturvation	To understand what NBS can achieve in cities, foster innovations, and realise the potential of NBS	Horizon 2020	2017–2022	https://naturvation.eu/
Sweden	Urban Nature	Identify drivers and barriers for NBS implementation as well as models and support structures facilitating the integration of NBS in the planning process	Formas	2017–2023	Urban nature Centre for Environmental and Climate Science (CEC) (lu.se)

4.1.3 Research publications from the Nordic countries focusing on NBS

We performed a structured synthesis of the peer-reviewed scientific publications (including only publications that use the term 'nature-based solutions' [NBS]) up until June 2021. World-wide, a total of 912 peer-reviewed publications included the term NBS. Out of these publications, 64 covered research related to the Nordic countries.[6] The publications mainly reported results from empirical and modelling studies (53 publications), but some also included results from review studies (13 publications). Most Nordic research came from Sweden (36 publications), followed by Denmark (21), Norway (14), Finland (11) and Iceland (2). About half focused on a single Nordic country, while the rest also included research from other countries (mainly other Nordic or European countries). The number of publications using the NBS term has increased over the years, especially in the last 3–5 years (Figure 5).

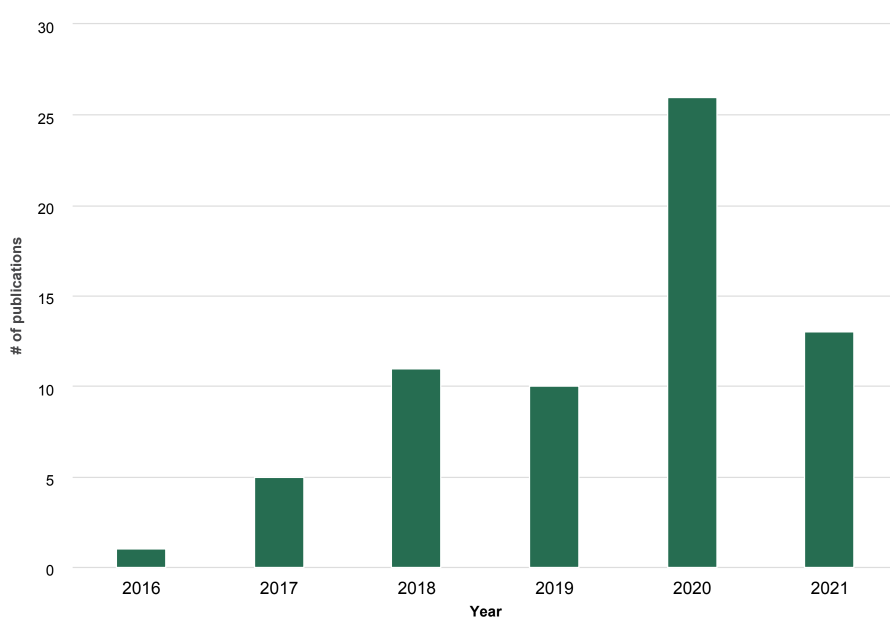

Figure 5. Peer-reviewed scientific publications in the Nordics (including publications that use the term 'nature-based solutions' [NBS]) until June 2021.

The studied NBS varied from large-scale ecosystem-based approaches (e.g., re-forestation of riparian areas to reduce risk of disasters) to small-scale NBS (e.g., biological infiltration beds for purification of runoff water). Most of the studies assessed functions of the NBS in relation to biophysical qualities, such as water

6. See S-ITUATION online material: https://www.niva.no/nordicsituation

retention capacity, flood risk reduction, health benefits and biodiversity contributions, but there were also studies focusing on potential economic benefits. Some studies compared different types of NBS, while others compared NBS with grey infrastructure solutions. There were also studies comparing similar types of NBS across different land-use contexts. The urban context was the dominant land-use context, covered in 50 publications, followed by freshwater (12), agriculture (5), forest (5) and coastal/marine (4). For an overview of publication number and land-use types across the five Nordic countries, see Table 4.

Below, we give a brief overview of the types of NBS that have been the focus of publications across the different land-use contexts.

Table 4. Countries and land-use types covered by the 64 NBS publications. Note that a single publication can include several Nordic countries and several land-use types. The total sum therefore exceeds 64.

	ECOSYSTEM / LAND COVER				
Country	**Agriculture**	**Coastal/ marine**	**Forest**	**Freshwater**	**Urban**
Denmark	4	3	2	2	17
Finland	1	2	2	2	8
Iceland	1				1
Norway	1		2	4	9
Sweden	2	1	3	8	26

Agriculture

The focus of the five agricultural NBS publications was mixed. One reported on results from a study focusing on *agroforestry*, including Denmark and Sweden among other countries. Another asked whether Danish farmers would be willing to *periodically flood their farmland* to reduce urban flood risks if they gained economic compensation. One focused on *farming to promote human health and wellbeing*. Another looked at the superior effect of NBS for the sustainability enhancement of catchment systems by *promoting desirable soil and landscape functions*. This study reviewed key examples and included several land-use contexts and examples from Sweden.

Coastal/marine

The focus of the four coastal/marine NBS publications was the effects of climate change on coastal and marine areas. One study focused on climate mitigation and covered both coastal and freshwater wetlands and performed a meta- analysis, which included a study of the cost-effectiveness of wetland restoration for climate change mitigation. Two studies focus on climate adaptation. One developed a framework for the design process of large-scale NBS solutions aiming to address biodiversity degradation. This is being tested in an urban-coastal case study in

Odense, Denmark. Another used Open-Air Laboratories to model the effectiveness of different types of NBS, such as dunes and seagrass, and included case-studies from Finland. The last study focused on the relationship between growing up in natural environments and subsequent psychiatric disorders in Denmark. All publications do also cover other land-use contexts.

Forest

The focus of the five publications was water management in forest environments; two of the studies also included freshwater. One study reviewed different economic approaches to address management decisions in forested watersheds. Another empirical study focused on the effect of *planting newly forested riparian buffers* on water-management capacity and covered Sweden and Norway. Another study investigated and compared hydroclimatic changes across a set of basins in the Nordic region (i.e., Finland and Sweden) and northwest America and compared these with changes in vegetation density (using the normalized difference vegetation index (NDVI)) across three time periods: 1973–1978, 1993–1998, and 2013–2016.

Freshwater

The main research focus of the twelve freshwater NBS publications was the use of NBS for stormwater, flood and disaster risk management, including empirical, modelling and/or governance studies. The studies cover solutions such as *wetlands, floodplains, riparian forest plantations and riparian habitats*. One publication reported results from a study investigating the potential of wetlands to dampen temporal variability of water flow through the landscape in 82 Swedish catchments. Another report documented results from a study investigating whether wetland ecosystems at local and regional scales can contribute to achieving the SDGs and their targets in Sweden. Another publication describes a Horizon 2020 Innovation Action (PHUSICOS) aiming to demonstrate the use of NBS in rural and mountain landscapes, including Norway, to reduce the risk posed by hydro-meteorological hazards. There were also publications focusing on water purification, including a publication describing an empirical study in Sweden about the potential of zebra mussel farming for nutrient retention in a eutrophic lake.

Urban

As there were 50 publications that focused on the urban land-use context, this category was the richest and most diverse in relation to the solutions covered. The most frequently covered societal challenges were urban flood risks and human health and wellbeing, but there were also publications covering other societal challenges, such as heat stress, air quality regulation and carbon sequestration. Several studies presented results from empirical and modelling studies, which focused on either climate change adaptation, water purification or these two in combination. There was a wide variety of NBS covered by the different studies. These included *constructed wetlands, bioretention basins, biological infiltration beds, sludge treatment reed beds, sedimentation ponds, green roofs, daylighting piped streams* and associated implemented NBS, urban farming combined with closed loop systems for sustainable water, nutrient, and waste management. Other studies provided results from empirical and modelling studies focusing on the benefits provided by different types of NBS for human health, wellbeing and/or food supply. Studied NBS included *communal urban gardening, urban and peri-urban agriculture, parks, nature rehabilitation gardens, greening of rooftops, edible green infrastructure, urban green (blue) infrastructure/space and greening initiatives/case studies* to promote health benefits, through recreation, stress reduction, physical activity etc. There were also studies focusing on governance structures for implementing NBS for urban societal challenges, including research topics such as collaborative planning, mainstreaming, flood management approaches, and practical NBS implementation. Many of the studies contextualised NBS as green infrastructure or ecosystem-based adaptation measures. The scope of the studies ranged from empirical studies based on interviews or document analysis, to reflection and conceptual publications, developing frameworks and guiding principles to support the planning, implementation, and management of urban NBS.

4.2 Policy frameworks and support for NBS in Nordic countries

Since the World Bank first used the term nature-based solutions in 2008, the concept has been adopted by the international research and policy communities over time, including the European Commission (European Commission, 2015; EEA, 2021) and to varying degrees in the Nordic countries. This is also reflected in environmental governance and planning. The policy frameworks in the different countries consist of both formalized rules and legislation, and more informal or voluntary measures encouraged by various policy instruments, strategies or guidelines. These create the conditions for the promotion and implementation of nature-based solutions, from the national to the local level. While not all Nordic countries have yet adopted the term NBS to the same extent, they all work with similar concepts (e.g., blue-green infrastructure) or address it by using established terms such as conservation or restoration. In this report we evaluate policies and regulations that specifically target the concept of nature-based solutions. However, we underline that there are also regulations covering measures that are similar to NBS that are not described here (e.g., subsidies for environmental measures in agriculture). In the following chapters, we will go into further detail about the governance conditions for NBS in the respective Nordic countries by answering the following questions:

- For what purposes are NBS adopted/suggested? Which societal challenges are they expected to address? What ecosystems are targeted? Do the publications specifically address biodiversity? If yes, how? (Chapter 4.2.1)
- Are there formal requirements for adopting and implementing NBS? If yes, on which governance levels and for which sectors? (Chapter 4.2.2)
- What kind of support (guidelines, scientific reports, financial, etc.) is provided to facilitate NBS planning, implementation and maintenance, long-term management and monitoring? (Chapter 4.2.3)

The questions were addressed through a search of the grey literature and policy documents in each country, using a common set of instructions and templates. The search directly targeted national governments and relevant national governmental bodies, regional and local authorities, and the main academic institutes. In addition, the national academic databases and Google were used to uncover any remaining relevant publications. For more information about the methods, see methods chapter 3.2.

4.2.1 Societal challenges and ecosystems addressed in Nordic policies

Societal challenges

The definition of NBS states that these are actions that should address societal challenges and be beneficial for biodiversity at the same time (see chapter 2). IUCN specifies that NBS interventions can address societal challenges like climate change, disaster risk, food security, human health, water security, and economic and social development among other things (IUCN, 2020). In the Nordic countries, the focus has been on climate change mitigation and adaptation, improving biodiversity, reducing pollution, and enhancing human health.

Denmark has a long history of action to mitigate societal challenges related to environmental issues, in particular nutrient pollution and recently, an increasing number of actions were also taken to reduce climate gas emissions. These actions include the implementation of constructed wetlands, rewetting of former agricultural land and low-lying soils (that still have remnants of organic carbon >6%) and afforestation. These actions can all be regarded as NBS as they fit the NBS standards (IUCN, 2020). Urban systems are currently the frontier for the implementation of NBS, to provide solutions for storm and rainwater events, and it is furthermore recognized that there is large potential for increasing urban quality and to enhance the connection between people and nature (SLA, 2019).

In **Finland,** over half of the implemented NBS projects found in the grey literature focused on urban and other "artificial" (constructed) environments and their associated land use. Much less information was found for forests, freshwater, agricultural and coastal environments. Note, however (addressed in more detail below), that NBS were currently used in forestry, but that the term NBS was not used to describe the practices. This problem with terminology probably affects the detail of information found for the other environments in Finland too. As in other Nordic countries, most information about NBS is written in general terms and thus relevant across ecosystems.

Iceland has recently started focusing on NBS. Solutions thus-far have tended towards environmental engineering rather than purposeful implementation of NBS per se. University research and the national authorities are at the forefront of introducing the term and carrying out projects. National and regional authorities are starting to embrace the concept, which may lead to increased demand and funding available for true NBS projects. This has led, very recently, to an increasing number of practical workshops and seminars discussing the topic, as well as some publications. Various groups use the term 'nature-based solutions' as an umbrella term for blue-green solutions, a concept which is already widely used in Iceland. It is therefore expected that NBS will gain more attention in Iceland and new publications will follow in the near future. Societal challenges that these projects need to address range from flood hazards, habitat regeneration to increase biodiversity and plant life, wetland restoration to coastal protection.

In **Norway,** the main focus on NBS is in the context of climate adaptation and treatment of runoff from roads, agriculture and to some extent from contaminated soils. NBS are also mentioned in the context of marine protection areas. NBS were first mentioned in the Norwegian context in an article on measures for road runoff treatment (Myrabø & Roseth, 1998). In fact, nature-based sedimentation ponds and infiltration solutions have been implemented for many years in the road transport sector to treat road runoff. Although the NBS term has been adopted in Norway, some cities are still using the term blue-green infrastructure in the urban context.

In **Sweden**, the primary focus of most of the publications and other written material on NBS has been on climate change adaptation. This is not surprising, as climate change adaptation is a major challenge in a Swedish context. This has mostly concerned how to handle downpours and stormwater in general, and less on heat waves and droughts. Many publications also focus on the contribution of NBS to human wellbeing and biodiversity. Quite often it is stressed that NBS include multiple solutions, which is highlighted as a strength to solve societal challenges in general.

Biodiversity

The definitions of NBS (see chapter 2) all agree that they are interventions that provide environmental benefits. Moreover, both the IUCN and UNEP definitions specify that NBS provide biodiversity benefits. Consequently, it is important that governmental requirements and support for the implementation and maintenance of NBS reflect this aspect, to ensure that the interventions do in fact contribute positively to biodiversity.

In **Denmark**, the term biodiversity is mentioned as part of the discussion about NBS, but without any real, concrete focus on how NBS can support biodiversity, and without clear targets. NBS and biodiversity issues are mentioned most often in relation to urban systems, as well as in projects aimed at primary climate adaptation in forests, freshwater and marine systems. Most focus on biodiversity comes from other frameworks, such as the new nature and biodiversity package from 2020 (WWF, 2020). With restoration efforts in, for example, peatlands and forests, there are obvious synergies between biodiversity enhancement and climate change mitigation, even if these are not expressed using the term NBS (Dinesen et al., 2021). Urban systems differ from natural ecosystems in that there is no target reference state for biodiversity, instead there is a vague concept of bringing nature back into cities and creating wild, green and blooming lushness via rain gardens, swales and green roofs (State of Green, 2021).

In **Finland**, most material about NBS touches on biodiversity only superficially. However, it is important to realize that, for example, forestry-NBS information seldom used the term NBS, although many operations fulfilling NBS criteria were commonly applied in Nordic managed forests. Nordic experimental set-ups on forest-management methods alone, to date, have produced more than 140 peer-reviewed assessments of aspects of NBS (see S-ITUATION supplementary materials in appendix 9.1).

In **Iceland,** several publications mentioned that one of the benefits of NBS is to increase biodiversity, especially in bird life, without explaining in detail how they are meant to increase such biodiversity. The Icelandic Land Reclamation Plan (Landgræðsluáætlun 2021–2030, 2021) promoted green infrastructure in and around urban areas and sustainable solutions to reduce the effects of floods caused by rainfall or runoff. These will protect and promote biodiversity in general. It also mentions that protecting, restoring or using ecosystems sustainably promotes biodiversity. Other examples of projects that aim to increase biodiversity include building shelter beds around fields, binding soil with vegetation that doubles as habitat or food sources for animals and afforestation with native trees. Wetland restoration projects also focus on biodiversity gain of aquatic species.

In **Norway,** there is a need for more knowledge and guidance about using NBS to preserve biodiversity, according to a survey which targeted public administration (Aanderaa, et al., 2021). Many relevant publications briefly mentioned benefits for biodiversity as an argument for implementing NBS. Biodiversity is covered more thoroughly in some research reports, as well as a white paper about marine protection (Ministry of Climate and Environment, 2021b) and a report about using NBS to address climate challenges (Norwegian Environment Agency, 2018). Some publications explicitly mentioned that NBS could negatively impact biodiversity, for example, by choosing invasive and alien species, and that awareness during the planning phase of NBS was important (Magnussen, et al., 2017). In that regard, references were made to the Nature Diversity Act.[7] Overall, however, publications rarely focused on the biodiversity impact of NBS.

In **Sweden**, most publications mention biodiversity when discussing NBS, mainly at a general level with biodiversity seen as a co-benefit from the implementation of NBS. Many reports suggested that biodiversity benefits were an argument for implementing NBS. In a report from the Swedish Environmental Protection Agency (Naturvårdsverket, 2021), there was clear guidance on how to "think about" the benefits of NBS in relation to climate adaptation, ecological and social aspects as well as how to identify and prioritize relevant solutions, as well as examples of NBS from different types of land use (in the report called landscapes).

Ecosystems addressed in the Nordic grey literature and policies on NBS

An important part of the review of Nordic grey literature and policies was to discover which kinds of ecosystems or NBS have been addressed in the publications, to understand if these are covered equally or if there are some ecosystems that have been addressed more than others. The analysis distinguished between ecosystems like the coastal or marine areas, forest, freshwater (including wetlands), agricultural land, urban areas/artificial NBS, and NBS in general.

Most policy documents and guidelines (Figure 6A) in the Nordics addressed NBS in general terms (70), while others targeted individual ecosystems, such as urban and artificial (61), freshwater (32) and coastal and marine ecosystems (23). When it came to reports (Figure 6B) the picture was different – most publications addressed urban and artificial followed by NBS in general (35), coastal and marine ecosystems

7. https://lovdata.no/dokument/NL/lov/2009-06-19-100

(22) and freshwater (21). Forest ecosystems and agriculture were addressed less, suggesting that the NBS term is not commonly used for those ecosystems and sectors (see chapter 4.4.3 for alternative terms that are used in Nordic forestry).

There were clear variations between the countries in terms of which ecosystems were addressed in policy documents focusing on NBS. Generally, in Denmark, urban and coastal systems were targeted most often, followed by forest and freshwater systems and, to a lesser extent, agriculture. NBS were sometimes mentioned in a general way, i.e., not specifying any ecosystem. Finnish documents mainly focused on NBS in the context of urban and other "artificial" environments, which covered more than half of the identified materials (16). Fewer documents were found for forests (8), freshwater (8), agricultural (7) and coastal environments (4). In Iceland, most mentions of NBS were general rather than detailing specific ecosystems. Projects that could be classed as NBS targeted forest and freshwater ecosystems foremost, with some documents on the coastal and marine ecosystems mentioning NBS. In Norway, many publications, such as policies and information pages, exist on NBS in general, and are relevant for many or all ecosystems. Urban or artificial NBS were often addressed because many publications refer to NBS in context of climate adaptation or treatment of road runoff. Quite a few publications addressed NBS in relation to rivers, streams and wetlands, often in the context of climate adaptation or mitigation (wetlands). In Sweden, the uptake of the concept of NBS has mainly been in the context of the urban and artificial ecosystem, followed by marine/coastal, freshwater and forest. The concept has gained less attention in agricultural ecosystems. Many publications also mention NBS in general.

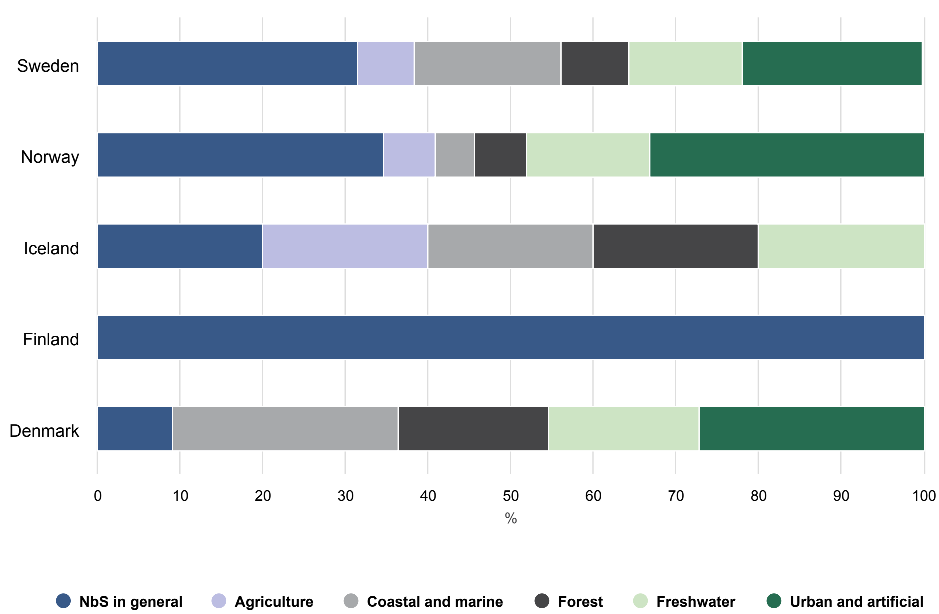

Figure 6A. Ecosystems addressed in policy documents (incl. laws, regulations, strategies and plans) and guidelines reports (e.g., research reports, status reports, analysis and more).

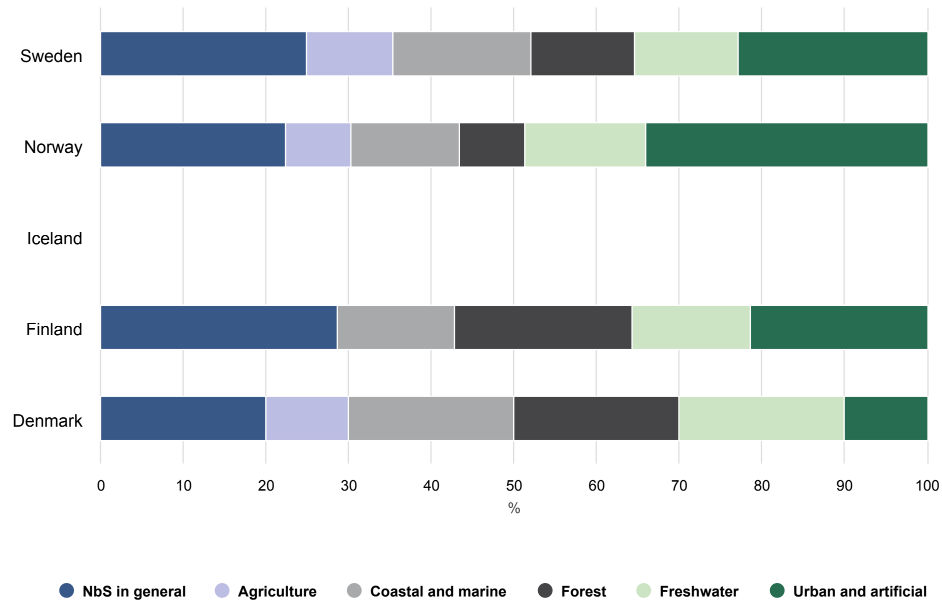

Figure 6B. Ecosystems addressed in policy documents (incl. laws, regulations, strategies and plans) and guidelines mentioning NBS specifically.

4.2.2 Governmental requirements for adopting NBS

Legislation, policy and strategies are important for setting the priorities of the public authorities and other relevant sectors. In the following chapter, the formal requirements for adopting NBS in the Nordic countries are assessed. These include specific requirements for the consideration of the use of NBS in certain settings, or the prioritization of it over grey solutions. We also look at whether there are specific requirements or conditions in laws and regulations where NBS are required, as well as looking at documents that are less binding, such as governmental white papers, strategies and plans adopted by national, regional and local governments and public bodies.

As EU member states, Finland, Denmark and Sweden are obliged to transpose EU legislation into national law, while Iceland and Norway are also implementing most EU directives and regulations through the EEA agreement. EU directives and strategies on water, flooding and biotopes (e.g., the Water Framework Directive, the European Climate Law, the Birds and Habitats Directives, the Biodiversity strategy for 2030) create frameworks for the development of policies and objectives, as well as providing support for NBS schemes. The European Commission (2022) also highlight that "Nature-based solutions support major EU policy priorities, in particular the European Green Deal, biodiversity strategy and climate adaptation strategy, as a way to foster biodiversity and make Europe more climate-resilient". In the agricultural sector, the EU Farm to Fork Strategy aims for sustainable and environmentally friendly food production. Through the Common Agriculture Policy (CAP), sustainable practices in agriculture are supported through subsidies dependent on cross-compliance.

When comparing the Nordic countries, it is evident that they are in different stages of development when it comes to mainstreaming the concept of NBS into policy – Norway and Sweden have adopted the term to a larger degree than Denmark, Finland and Iceland. Still, all five countries conserve, restore and work actively on developing the sustainable use of nature, but use other terms (e.g., 'blue-green infrastructures or solutions', 'restoration', or 'ecosystem services'). Here, the review is limited to documents and publications that specifically include the term 'nature-based solutions' or 'NBS'. Table 5 gives an overview of whether policies using the term NBS were found in the different countries.

Table 5. Use of the NBS concept in policy in the Nordic countries.

Document type	Denmark	Finland	Iceland	Norway	Sweden
Laws and regulations	No	No	No	Yes	No
Policies, strategies and plans	Yes	No	Yes	Yes	Yes

The NBS concept is not integrated in the legal structure in most of the Nordic countries, with the exception being Norway. The uptake of the concept in strategies and policy texts is more frequent, especially in Norway and Sweden. All countries do, however, have legislation, strategies and policies that support the implementation of NBS, even if NBS are not mentioned specifically.

The government of **Denmark** has not adopted the NBS concept in their legislation, policies or strategies. The term NBS is used in some documents from the Ministry of Environment, to give an outlook on the future implementation of restoration measures, like the rewetting of organic lowlands agricultural areas. It isn't, however, consolidated in their governmental frameworks or used to formulate any specific requirements to be addressed by public or private actors. Nevertheless, some municipalities have adopted policies which include NBS. Vejle municipality's storm surge strategy action plan suggests several kinds of NBS amongst other measures, while Odense municipality seek to implement NBS according to their climate action plan.

Finland has not, at any administrative level (national, regional and municipal), adopted the NBS concept or any requirements for adoption. However, given that NBS are widely understood to include restoration, rehabilitation and close-to-nature environmental management, Finnish legislation (without mentioning NBS specifically) forces the landowner or land manager to carry out certain NBS actions. These mostly relate to the protection of water quality in ground water, lakes and streams, and conservation of habitat types of known importance for biodiversity (key biotopes). Examples are the Finnish Nature Conservation Act, Forest Act, Water Act, The Sustainable Forest Management Funding Act (KEMERA), The Forest Biodiversity Programme of Southern Finnish Forests (METSO), and the HELMI environmental programme.

In **Iceland**, there are currently no binding governmental requirements for adopting NBS. However, national authorities have repeatedly stated an interest in and a willingness to push for the implementation of nature-based solutions in general terms. They often mention afforestation – a historic issue in a soil-poor, erosion-prone country – as well as reclaiming wetlands to store carbon and help with flooding issues. On a regional and local authority level, the NBS term has not been adopted yet. However, there are efforts called blue-green surface water solutions in Urriðaholt municipality and rain gardens and surface water solutions in the municipality of Reykjavík. At a larger scale, there are projects targeting soil erosion of agricultural land all around the country.

In **Norway**, several public sectors are involved in, have requirements and provide support for implementing nature-based solutions. These efforts relate mainly, but not exclusively, to climate change mitigation and adaptation, or stormwater treatment. In the road transport sector, nature-based sedimentation ponds and infiltration solutions for treating road runoff have been part of the standard for road construction for certain roads since 2005 (Norwegian Public Road Administration, 2005; 2011; 2014b; 2018; 2021). Conservation and restoration of peatlands and other wetlands are considered important for climate change mitigation and therefore, the cultivation of new land (i.e., new fields for agriculture) is not allowed in peatlands, and the government is considering additional measures (i.e., regulation, fees) to reduce degradation of peatlands, whilst restoring already degraded peatlands. Most of the work on NBS in Norway relates to climate adaptation. For land-use planning, the national authorities adopted a legally binding governmental planning guideline for climate and energy planning and climate adaptation (Ministry of Climate and Environment and Ministry of Local Government and Modernisation, 2018). This requires that conservation, restoration and NBS must be considered in climate adaptation planning and if these are not then included, the reasons for omitting them must be justified. Some municipalities have taken this guidance into account in their master plans and other zoning plans (e.g., Stavanger, Hemsedal, Bærum), and it is referred to in consultation responses by County Governors and other state agencies. For climate adaptation, blue-green infrastructure as a concept has been adopted in several Norwegian municipalities (e.g., Oslo, Trondheim, Lillestrøm, Bergen, Gjerdrum), of which some may be considered NBS.

In **Sweden** the term NBS is not included in the existing legal frameworks. However, given that NBS include restoration, rehabilitation and close-to-nature environmental management, Swedish legislation (i.e., Swedish Environmental Code, Forestry Act), although it doesn't mention NBS specifically, forces the landowners or land managers to carry out certain NBS actions. These mostly relate to the protection of water quality, including ground water, lakes and streams, and the conservation of habitat types of known importance for biodiversity (key biotopes). In addition, there are several policies supporting the implementation of NBS, linked to policies in different sectors, such as Water framework directive, Flood directive and CAP third pillar. In addition, there are nature conservation policies related to restauration or conservation of land that, even though NBS may not be explicitly mentioned, support the implementation of NBS-like features, in relation to protected land as well as in forestry.

4.2.3 Support material provided to facilitate NBS implementation

Whether NBS are required by law, by policies or not explicitly required, the public administration provides different forms of support to facilitate NBS planning, implementation and maintenance. It may come in the form of guidelines directly tied to national legislation or policies, guidance on how to implement or maintain NBS in practice, financial support, or in-depth knowledge and commissions to provide the necessary knowledge basis for decision-making. The support may come from public authorities, academic institutions, consultancies and other private actors.

In this chapter, we will highlight some of the support material provided in the Nordic countries to facilitate NBS planning, implementation and maintenance, long-term management and monitoring. We differentiate between guidelines, tools and in-depth knowledge targeting practitioners and public administration. Note that this chapter focuses on documents and reports specifically using the term NBS, and there may be other relevant publications, support schemes etc. which are relevant for NBS but using other terms.

Guidelines and tools

Few examples of guidelines were found for the implementation and maintenance of NBS in practice in Denmark and few municipalities were on their way to create more sustainable urban communities. The exceptions include Vejle, a coastal city, which has developed a comprehensive storm surge strategy (Vejle municipality, 2020) to protect the citizens while at the same time raising the quality of life. Odense municipality has developed a detailed climate action plan (Odense municipality, 2021), to become greener and climate neutral by 2030 and which already includes NBS measure in forests, lowland areas and coastal zones. It is involved as partner in a targeted EU research proposal. Regarding climate adaptation, the Swedish Environmental Protection Agency published a report defining and explaining the NBS concept, while providing guidelines for implementing NBS and a collection of examples of implemented NBS in different land-use contexts (urban, freshwater, coastal, forest and agriculture) (Naturvårdverket, 2021). The Norwegian Public Road Administration (2014a; 2006) published a report on water protection in the road sector which described treatment methods (incl. NBS) for road stormwater runoff. For each treatment method, the report included a sketch, principles for design, dimensioning and operation, and a short summary of experiences and treatment effects. Another example is the process guide published by the County Authority in Rogaland (2021), Norway, which guides the reader through relevant legislation and policies, explains NBS for climate adaptation and the climate change impacts they address, gives several examples of NBS in the county, and provides recommendations for the governance process and checklists.

In addition, public authorities in some countries provided supporting material for the governance processes related to climate adaptation, stormwater and flood management, e.g., guidelines for land-use planners (Norwegian Environment Agency, 2019; 2021a; 2021b; 2022; Norwegian Water Resources and Energy Directorate, 2022). These documents often mention NBS briefly or in dedicated sub-chapters but are rarely guiding the practical implementation or maintenance of NBS. Tools and other resources have been developed by KLIMA2050, a Centre for Research-based

Innovation (SFI) in Norway, focusing on the climate adaptation of buildings and infrastructure as well as other checklists, a toolbox for landslide risk mitigation, and a NBS documentation tool (Raspati, et al., 2019; Andenæs, et al., 2022; Sivertsen, et al., 2021; Capobianco, 2020).

In-depth knowledge targeting practitioners and public administration

Publications containing in-depth knowledge about NBS can be categorized in two main types, namely publications that provide knowledge about NBS specifically, and publications that support governance processes related to NBS.

Quite a few publications provide knowledge about specific NBS, while others synthesize the current knowledge about NBS in general or are related to specific sectors or topics. A Norwegian consultancy, commissioned by the Norwegian Environment Agency, published a report providing descriptions, examples and assessments of the effectiveness, cost, status of knowledge level, suitability, co-benefits of different NBS (Magnussen et al., 2017). A research project in Denmark post-evaluated different NBS case studies in coastal areas to draw recommendations and a framework for how NBS can be implemented to recover the ability of coastal areas to filter nutrients, capture fine particles and maintain a rich biodiversity of flora and fauna (Quintana et al., 2021). They emphasized the urgent need for more competencies around environmental and architectural aspects, as well as administrations and societal sectors to support the planning and implementation of NBS in coastal protection.

Some publications examined or aimed to support the governance processes related to NBS. In 2021, a consultancy assessed the Norwegian public administrations' needs for knowledge, guidance and user support for NBS for climate adaptation in Norway (Aanderaa et al., 2021). The report concluded that it is not sufficient to create even more guidelines aiming to promote the more extensive use of NBS. Instead, various factors need to be addressed, such as raising knowledge among elected officials, increasing the financial allocations for climate adaptation, collecting and disseminating experiences with NBS, clearly emphasizing the requirements for NBS, enabling more pilot projects, and allowing for trial and error.

Financial support

In the Nordic countries, few schemes for financial support were found that specifically targeted NBS. **Norwegian** authorities provide a regional environmental subsidy for agriculture, in which NBS for climate adaptation are eligible for funding according to a comment in the funding scheme (Norwegian Agriculture Agency, 2020). The Norwegian Environment Agency also provide grants annually to municipalities and county authorities for knowledge-building projects and assessments of climate adaptation measures. Several projects that received funding in 2021 were related to NBS and restoration efforts (Norwegian Environment Agency, 2021c). In **Sweden**, several public authorities have provided funding for different projects that include the use of NBS, related both to nature protection (so-called LONA funding) and to different types of climate adaptation activities. This includes greening activities in cities, such as planting trees in school yards, and the implementation of wetlands to handle stormwater and improve water quality in both urban and peri-urban environments. However, these funding opportunities have not been tagged with NBS, but generally come under urban green space, green infrastructure, water quality etc.

The fact that only two examples of financial support programs for NBS were found in the Nordic countries supports our observation about the lack of public and private funding (see chapter 5.2). The Nordic Council of Ministers' nature-based solutions programme aims to change this. They are encouraging the Nordic countries to work together, to enhance their knowledge-base and they have funded the implementation of several NBS projects across the Nordic countries.[8]

4.3 NBS projects implemented in Nordic countries – Nordic NBS case projects catalogue

The S-ITUATION partners collected 54 cases of implemented Nordic NBS projects.[9] Projects were included if they simultaneously aimed for a biodiversity net-gain and addressed one or more societal challenges. These minimum inclusion requirements reflect criteria 1 and 3 of the IUCN general standard for NBS. Given the resources available in S-ITUATION, the collection neither provides a complete picture of NBS projects in Nordic countries, nor a representative sample of Nordic NBS. It does, however, bring together the breadth of NBS projects that were carried out in the Nordic countries up to 2022 and enabled us to identify interesting examples of Nordic NBS case projects. Out of the 54 NBS projects included in this report, most (17) were related to freshwater, 12 covered urban/artificial NBS, 11 each for forest, peatland and marine/coastal and 8 were in agricultural areas. The remaining 4 projects included wetlands (not peatlands), restoration of native vegetation on road verges and one project on the restoration of vegetation in the highlands of Iceland. The average size of the reported NBS projects was 945 hectares, ranging from small projects (0.01 hectares) to large projects covering 5200 hectares. Even though S-ITUATION partners were asked to contribute NBS cases which covered all three of the IUCN categories (conservation, restoration, sustainable use), only 4 projects were collected which fell into the category "conservation", whereas 36 were restoration projects, and 14 projects fitted the sustainable use category. Looking at the implementation of Nordic NBS case projects over time, there has been an increase in the number of projects between 1990 and today and especially in the last decade (Figure 7).

8. Nordic Co-operation, Nature-based Solutions. https://www.norden.org/en/project/nature-based-solutions
9. See S-ITUATION online material: https://www.niva.no/nordicsituation

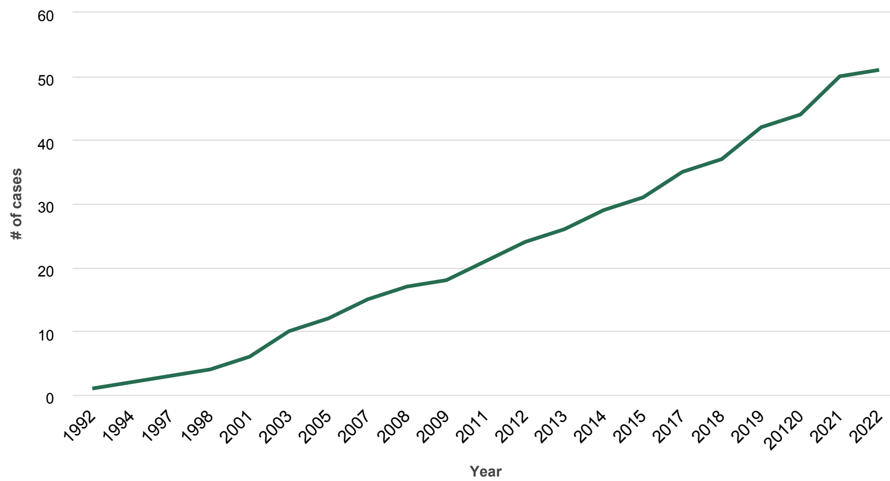

Figure 7. Nordic NBS case projects implementation over time, cumulative curve. *Data source: Nordic NBS project catalogue (N=51)*

According to IUCN, there are seven major societal challenges that should be addressed with NBS. While NBS projects usually aim to address one or two of these challenges (Figure 8), they provide additional secondary benefits. The impetus for most of the case projects in this study was to address environmental degradation and biodiversity loss (Figure 8). Climate change mitigation and adaptation, disaster risk reduction and economic and social development were each listed as challenges by around 50% of the collected NBS project cases. Secondary benefits of Nordic NBS projects included recreation, several ecosystem services, improved water quality, aesthetic improvements and wave attenuation (in decreasing frequency).

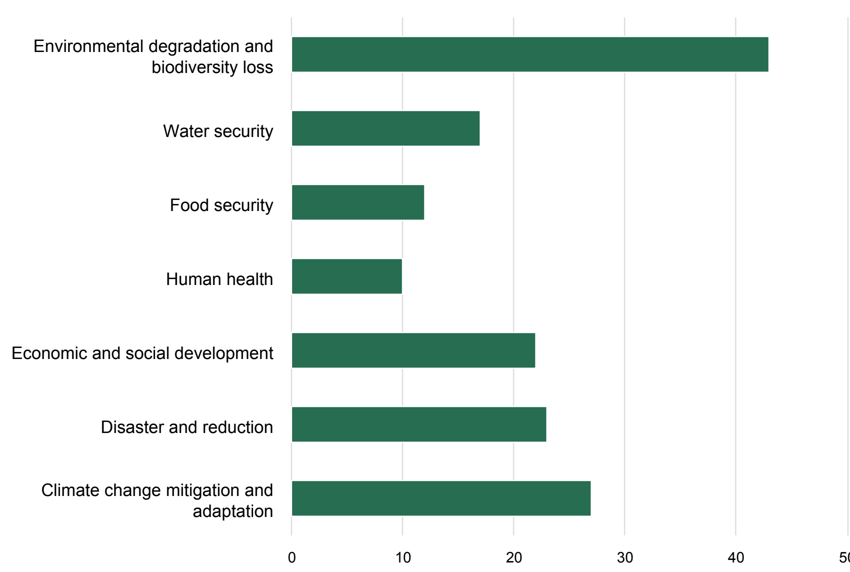

Figure 8. Main societal challenges to be solved by Nordic NBS case projects (N=54); multiple answers per NBS project were possible; the categorization of challenges follows IUCN criteria 1 (see IUCN, 2020).

In terms of biodiversity net-gain, the case projects refer most often to increases in abundance (number of individuals) and species richness (number of different species). Provision of a larger habitat area or improved habitat connectivity were also mentioned, as they are expected to lead to biodiversity gains. Five projects specifically mentioned the preservation or recovery of endangered species as biodiversity net-gain. However, based on the information available, it is often not clear if the intended biodiversity benefits are regularly monitored, quantified and assessed after the completion of the project. It also often remains unclear if the predicted benefits have been quantified or if only qualitative predictions have been made. Quantification of benefits can be an important pre-condition to attract funding (see chapter 5.2). For 30 projects (out of 54) it was reported that benefits were quantified, while they were not quantified in 10 projects and in 14 projects no information was available. Regular monitoring and evaluation was reported to be carried out in 28 projects. In 11 projects this was not done and for 15 projects this information was not available. Regular monitoring and evaluation of NBS projects is important to provide a better evidence-base on the success of NBS, as well as to enable adapted management as suggested by IUCN.

The economic viability of NBS projects had been confirmed only in 6 projects, where a cost-benefit assessment was performed beforehand. For 31 projects, no cost-benefit assessment was done and in 17 this information was not available. In 9 cases, the NBS projects were compared to alternative solutions, while this was not done in 27 projects and no information was available for 18 projects. This lack of cost-benefit information in the case projects matches our findings in chapter 5.2 on economic shortcomings.

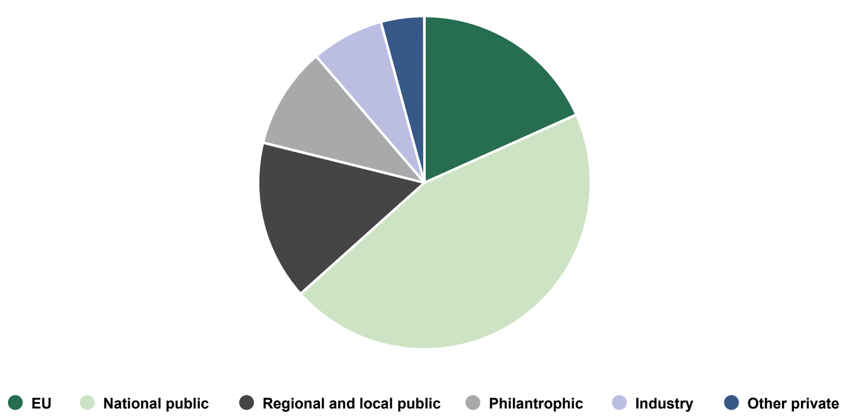

Figure 9. Funding sources used in Nordic NBS case projects (N=48); multiple answers per NBS project were possible; the figure does not show the share of funds coming from the different funding sources.

The funding sources for Nordic NBS case projects were most often national public budgets, followed by EU-funds (LIFE program, Interreg, European Agricultural Fund for Rural Development) and local public budgets (Figure 9). Private funding from individuals, philanthropic organizations or industry were involved to a minor extent in funding. The majority of Nordic NBS case projects were funded by more than one source. These findings for Nordic NBS case projects were comparable to the results from a 2018 study, where NBS projects across 100 European cities (including 7

Nordic cities) were assessed (Almassy et al., 2018). They found that private funding was only included in approximately 25% of the NBS projects. However, the proportion of projects reporting local and regional public funding was higher than in our set of Nordic NBS case projects.

4.4 Status of NBS implementation in Nordic Countries across land use types

Historically the economies of Nordic countries and the well-being of its citizens have relied on ecosystems and nature. Industrialization, urbanization, exploitation of renewable and non-renewable resources have put pressure on Nordic ecosystems and there is a need to conserve and restore them as well as to establish sustainable use practices in order to preserve them for future generations.

This chapter describes NBS used in different ecosystem/land use types, including agricultural, coastal and marine, forest, freshwater and urban/artificial settings in a Nordic context. The aim is to address: 1) different societal challenges, 2) expected biodiversity gains, and 3) what (if any) specific barriers/challenges/issues exist to the implementation of NBS. In the following chapters, for each ecosystem/land use type, we will: 1) categorize and list the NBS and 2) consider, in a general sense, to what extent these solutions are used in the different Nordic countries 3) briefly assess to what extent these solutions may contribute to a net gain for biodiversity and as well as 4) social benefits.

4.4.1 Agriculture

Figure 10. Before and after rewetting of Strande enge, Denmark – a former grassland area used for grazing and hay making.
Photo: Carl Christian Hoffmann, Aarhus University.

In this chapter, we will give an overview of what societal challenges can be addressed with NBS in the agricultural landscape. We will give examples of typical NBS in relation to agriculture in Nordic countries (Figure 10), including a discussion of the expected biodiversity gains and other benefits/societal benefits. We will also discuss specific barriers/challenges/issues related to implementing NBS in agricultural settings. Agriculture needs to handle several challenges and NBS can contribute to solving these.

Overview of what societal challenges can be addressed with NBS in the agricultural landscape

There are several societal challenges caused by crop production and animal husbandry. Nutrient leakage (nitrogen and phosphorus) is a major challenge in most agricultural systems. Nutrient leaching leads to reduced water quality of freshwaters and is a major contributor to eutrophication and algae blooms in the Baltic Sea, as well as in lakes and rivers fed by agricultural land. Other challenges include soil erosion, loss of soil organic carbon as well as the leaching of pesticides to the surrounding land and waterways. These effects can lead to reduced soil fertility, emissions of carbon dioxide, and reduced water quality in waterways as well as a loss of biodiversity. Agriculture also affects biodiversity negatively due to the loss and fragmentation of important habitats such as meadows, permanent grasslands and small biotopes. Many red-listed species are connected to the agricultural landscape, and they become marginalized when the size and connectiveness of habitats decreases. The loss of habitats also influences the number of pollinating insects, which can negatively affect the production of crops, vegetables and fruits that need insect pollination. Intensive agricultural production requires large land-areas, and this can limit opportunities for recreational activities. On top of these pressures, climate change adds additional challenges, such as droughts, extreme rainfall and erosion, which can reduce crop yields and negatively affect animal husbandry.

NBS can help to cope with many of these issues. For example, solutions could be designed to increase soil organic carbon, increased productivity and increased carbon storage. Different types of nutrient recycling systems can be developed. NBS can also ensure the access of humans in this landscape, facilitating access to recreation.

Examples of typical NBS in relation to agriculture in Nordic countries

Wetlands, ponds and diches (constructed or restored)
Wetlands in the agricultural landscapes fulfil different purposes. One main purpose is to purify run-off water from arable land by reducing nitrogen and phosphorus levels, thereby reducing eutrophication and nutrient transport to the sea. Depending on the main purpose, the geography of the area and the nutrient loads, NBS wetlands can range from smaller phosphorus traps to larger wetland areas. Research has shown that both created and restored wetlands significantly reduce the transport of nitrogen and phosphorus in agricultural runoff and may thus be effective in efforts to counteract eutrophication (Land et al., 2016).

In **Denmark**, there are ongoing, large-scale actions to re-establish riparian wetlands and shallow lakes. This is considered to be one of the most cost-effective solutions for the mitigation of diffuse pollution, so that lakes and rivers can achieve "good ecological status" within a reasonable timeframe (Hoffmann et al., 2020). Furthermore, different drainage mitigation measures are established, such as mini-wetlands or (still in the test phase) saturated buffer zones to reduce the non-point source pollution from agricultural drainage systems (Carstensen et al., 2020). In Sweden, constructed wetlands have long been used to decrease nitrogen transport from agricultural catchments to the coast. Studies have shown that the nitrogen removal varies depending on whether main purpose of the constructed wetland was to retain nutrients or to fulfil other purposes as well (e.g., biodiversity improvements) (Strand and Weisner, 2013). Another function of wetland areas and ponds is water retention, either to retain water for animal husbandry and crops during dry seasons or to slow down water runoff during downpours or rainy seasons. In Denmark, integrated buffer zones have been tested for their capability to deliver different ecosystem services, including water storage, as a subset of regulating services (Zak et al., 2019).

In **Sweden**, there is increasing interest in ponds, especially after the 2018 drought, in areas where there is a lack of fresh water. Wetlands and ditches to slow run-off are beginning to be built in flood-prone areas. Wetlands, ponds and ditches also contribute to agricultural biodiversity (Thiere et al., 2009). This contribution will depend on the size of the wetland and how attractive it is to, for example, different types of wetland birds and amphibians. A study from Sweden showed that birds and amphibians colonized constructed wetlands irrespective of the original objective of the wetland (nitrogen removal or biodiversity), but that some amphibian species preferred biodiversity wetlands (Strand and Weisner, 2013). These features can be important for the regional species pool and as part of a larger blue green infrastructure. The social benefits of that wetlands can contribute include recreational areas, scenic beauty as well as other cultural ecosystem services.

However, these social benefits are dependent on accessibility (paths, bridges), which can be limited in the agricultural landscape due to private land ownership.

Tree alleys, hedges shelter beds and the development of riparian zones

These features can be planted to protect soils and crops from wind and sun in a changing climate. In colder regions, tree alleys are also beneficial as they can lead to a warmer climate in the fields and, in hillier regions, hedges can reduce erosion. Hedges and trees in the agricultural landscape increase habitat diversity, which can support farmland biodiversity. Tree alleys and hedges can also make agricultural land more accessible for recreational purposes. In Sweden, hedges are not used to a large extent, while tree alleys are used in very windy areas, in areas with soil erosion problems and in areas of fruit production. In Iceland, shelter beds have been used in a similar way to hedges and alleys in warmer climatic zones. Leaving vegetation in the riparian zone untouched along streams and rivers is an NBS that has been in use for a long time in several of the Nordic countries. The focus has mainly been on their role in reducing nutrient leaching but also to protect waterways from pesticides, warming and soil erosion (Rasmussen et al., 2011).

Permanent grasslands and seminatural habitats

Permanent grasslands and seminatural habitats are important habitats for pollinating insects and some natural enemies of pest species. These can improve yields and reduce the needs for pesticides. There has been a global decline of these habitats, and an important NBS is therefore to protect, conserve and restore them. The Common Agricultural Policy provides some protection for these lands, but there is also increasing discussion of how policies targeting permanent grasslands could also target carbon sequestration and biofuel production.

NBS used on arable fields

There are several measures within the EU Common Agricultural Policy that could be classified as NBS. In non-EU countries, several of these agri-environmental measures feature in national agricultural policies. Grasslands and set asides reduce carbon leakage and soil erosion. They can also contribute to farmland biodiversity and pollinating insects as well as providing recreational possibilities in areas with intensive agriculture. In southern Sweden, so called "beträdor" (pathways) have been developed, which combine the needs for recreational opportunities and the protection of waterways from nutrients (examples from Staffanstorp[10] and Helsingborg[11]).

Flower strips, with annual flowers such as *Phacelia*, support pollinating insects and natural enemies of pest species. A global synthesis from 2020 demonstrated that flower strips enhanced the pest control services in adjacent fields by 16% on average (Albrecht et al., 2020). However, effects on crop pollination and yield were more variable. Important factors influencing pollination success were distance from the strip and the diversity of flowering plants (Albrecht et al., 2020; Jönsson et al., 2015). Swedish farmers have shown increasing interest in using flower strips. Projects have looked at how to increase the practical knowledge of flower types that support pollinating insects and natural enemies of pests and how these should be managed.[12]

Cover or catch crops (e.g., white mustard, Italian, ryegrass, radish) increase crop diversity and different types of crop rotation are commonly used to reduce nutrient leakage from arable fields, reduce soil erosion, and improve soil organic carbon quality. Cover crops are planted between two regular crops (often during autumn/winter periods) and are used to improve soil quality (soil organic matter), reduce soil erosion and nutrient leakage (Constantin, et al. 2010; Kaye and Quemada, 2017). Leguminous cover crops also reduce the need for fertilisers, due their ability to fix atmospheric nitrogen. These effects can help to reduce the runoff of fertilizers and pesticides to waterways.

New types of farming systems

There are also NBS of a more technical nature, such as a circular nutrient reuse system or the development of new farming systems in aquaponics that combine the production of fish and vegetables. These solutions mainly target nutrient recycling, but they could potentially free-up areas of former farmland for e.g., biodiversity habitats, if significant efficiency-savings can be achieved compared to traditional methods of farming. Another type of crop system is agroforestry, which can reduce soil erosion, benefit pollinating insects and promote biodiversity by providing flower resources. This farming system could also improve recreational opportunities in intensively cultivated arable farmland by creating accessible and attractive areas.

Expected and obtained biodiversity gains and other societal benefits from agricultural NBS

There has been substantial research about the contribution of NBS to farmland biodiversity. Whether or not different interventions positively affect biodiversity depends on the landscape context and which aspects of biodiversity are being targeted. Introducing NBS in heterogenous landscapes already rich in features promoting biodiversity (e.g., meadows, small biotopes, wetlands) should have a smaller overall contribution than where new habitats are introduced into

10. Staffanstorp kommun, Beträdor. https://staffanstorp.se/uppleva-och-gora/natur-kultur-och-sevart/friluftsliv-och-motion/betrador/
11. Grönstruktur i Skåne – Strategier för en utvecklad grön struktur. https://utveckling.skane.se/siteassets/publikationer_dokument/gronstruktur_i_skane.pdf
12. Hushållningssällskapet, Odla för nyttodjur. https://hushallningssallskapet.se/?projekten=odla-for-nyttodjur

homogenous, intensively-managed landscapes. Different interventions benefit different species. For example, generalist pollinators such as the short-tongued bumblebee species *Bombus terrestris* are known to benefit from the introduction of mass flowering crops and flower strips, while long-tongued bumblebee species, which forage on nectar and pollen resources from specific plant species/families, benefit from the restoration and establishment of meadows and permanent grasslands.

Specific barriers/challenges/issues related to implementing NBS in agriculture

Many factors influence the use of NBS in the agricultural landscape.

Economy: The available budget is obviously a major factor dictating the implementation of NBS. The size of the budget needed is determined by many factors. Is the implementation an intrusion into the land use rights of the landowner? Does the implementation need collaboration form different landowners and between landowners and other stakeholders (authorities, industries, NGOs)? The implementation of NBS needs a common language and knowledge base. If such a common ground is missing, the implementation becomes more difficult, misunderstandings become more common and implementation may be stalled.

Institutional structure (organization of authorities, law and policy): There is a complex set of factors related to institutional structures that can hinder the implementation of NBS. There is an increased focus on addressing barriers to the implementation of NBS in landscape planning systems.

Collaboration capacity: Many of the larger NBS must be developed in collaboration between several local stakeholders and how this is facilitated is key. Integration and balancing of benefits between geographical scales: Among the aims of NBS are improvements to climate adaptation, biodiversity, carbon capturing and recreation. NBS therefore operate from the global to the local scale. There is a need for a better understanding of the effectiveness of the different types of NBS across these scales.

4.4.2 Coastal/Marine NBS

Coastal and marine ecosystems are among the most biologically diverse on the planet, and all human life depends on the ocean. The ocean acts as a climate regulator, carbon sink and primary producer of oxygen. Humanity depends on the health of the ecosystems of the ocean and coast and on its flora and fauna. Coastal and marine ecosystems are under severe pressure from climatic changes such as acidification, warming temperatures and sea ice melt as well as from intense human activities like fishing, pollution, shipping, construction and drilling. The Arctic has been described as the fastest changing region on the planet (Thomas et al., 2022), mainly due to warming temperatures and sea ice loss. This will inevitably lead to altered ecological and physical realities, both in the Arctic itself and at lower latitudes (Overland et al., 2019). Coastal communities will notice some of these impacts first-hand, through flooding, changing weather patterns, biodiversity loss and species shift.

Overview of what societal challenges can be addressed with NBS in a coastal/marine context

One of the main challenges for NBS in coastal and marine ecosystems in the Nordic countries is to assess and restore key habitats that will allow multiple species to recover and thrive. It is widely accepted that marine vegetation such as eelgrass and kelp play a vital role, not only in producing oxygen and filtering water, but also as a crucial breeding ground and habitat for juvenile fish and many other marine species. Therefore, many NBS projects focus on restoring these vegetated habitats. Complex land-sea interactions take place in the coastal zone, where life depends on the uninterrupted flow of sediments, tides and waves. In many places, these processes have been disturbed by the construction of sea walls, harbours and shore development. Nature's own flood buffers, like natural sand banks, kelp forests and dunes, have been replaced by built structures that do not provide the same benefits. Nature-based solutions for the shore can re-create the previous flood protection that the coasts naturally offered, as well as re-establishing thriving coastal and marine ecosystems.

Climate change and biodiversity loss are affecting marine and coastal ecosystems severely. Species are under threat, or losing their habitat due to human activities, e.g., saltmarshes turned into agricultural land, coastal zones built up, or human-induced climatic changes such as acidification and ocean warming. These effects on marine species can have severe knock-on effects on terrestrial species, such as reduced numbers of salmon available for predators in mountain rivers due to impacts on the marine part of the fish's lifecycle. They also seriously impact human activities like commercial fishing, which many communities globally depend on. Common challenges that coastal and marine NBS are tackling include climate change adaptation, disaster risk reduction and environmental degradation and biodiversity loss, which in turn have impacts on marine resource stocks as a food source.

Examples of typical coastal/marine NBS in the Nordics

Examples of coastal and marine NBS include the restoration of reefs, restoration of saltwater marshes (Holmer et al., 2016), conservation or restoration of kelp forests (Tarevoktere, 2019) and restoration of eelgrass beds (County Administrative Board of Skåne, 2020). This is done in order to adapt to climate change and reduce flood risks, increase the water quality and oxygen production, stabilize the sediment and reduce the risk of erosion (Infantes, 2021) and to provide improved habitat for both flora and fauna in the coastal and marine ecosystems.

Restoration of kelp forests

In **Norway**, a project restoring the kelp forest in the Troms region is aimed at solving societal challenges like food security as well as environmental challenges like climate change adaptation and mitigation and environmental degradation and biodiversity loss. The volunteer organisation Tarevoktere[13] removes sea urchins from the seafloor both by culling and harvesting, thereby allowing the kelp to return. NIVA coordinates

13. Tarevoktere. https://www.tarevoktere.org/no/hjem/

the scientific research and monitoring of the kelp growth and biodiversity changes. The project increases biodiversity and biomass because the kelp forest provides a viable habitat for organisms living on the sea floor, on the kelp itself and in the forest (Figure 11). In addition, it is assumed that the return of kelp can contribute to carbon storage and wave damping. Although this restoration is currently taking place at only one site there are plans to expand the project to include a greater area.

Figure 11. Restoration of Kelp forests in Norway by removal of Sea urchins.
Photo: Pernilla Carlsson/NIVA.[14]

In **Iceland**, the concept of NBS has not historically been used to describe restoration projects. Therefore, there were no direct coastal and marine NBS to report on. However, the concept is currently widely discussed between researchers and practitioners, and a surge of NBS implementation projects is expected in Iceland the near future. To date, most projects with similar objectives have been described as blue-green solutions and often focus on increasing water quality and reducing flood risks. In recent years, hand-crafted, manufactured products have entered the food market in Iceland which are aiming to use the coastal and marine resources with minimal carbon footprint. Some NBS contribute to building habitats such as kelp forests and thus play an important role in maintaining and improving oceanic ecosystems. Specifically, the cultivation, and not just the harvest, of kelp is being trialled in several projects. Kelp can be grown in the sea on lines and offer an important habitat for many oceanic species, as well as a nursery for juvenile fish. In one project, Fine Foods Íslandica[15] is cultivating seaweed in Breiðafjörður in the Westfjords of Iceland for use in food products such as soups, salads and other dishes. The small company produces a seafood broth using Wild Icelandic mussels, sugar kelp, mushrooms and smoked fish, all of which are sourced from local producers (Fine Foods Íslandica, 2022).

14. NIVA, Restoring Norway's underwater forests: A strategy to recover kelp ecosystems from urchin barrens. https://www.niva.no/en/reports/restoring-norways-underwater-forests
15. Fine Foods Íslandica. https://finefoods.is/our-story-1

Restoration of reefs

In **Denmark**, the vast majority of NBS projects in the coastal and marine area are also focused on restoration, tackling climate adaptation and mitigation, environmental degradation and biodiversity loss and water security issues. Some have direct impacts on food security and economic issues such as strengthening the commercial fishery in Ringkøbing Fjord as a consequence of re-meandering the river Skjern (Pedersen et al., 2007).

Many of the projects target large areas of between 5 and 2000 ha. The smallest scale project to date is the introduction of a stone reef at Læsø Trindel in Kattegat by adding the structure and function of cavernous boulders in a soft-bottom area (Naturstyrelsen, 2013) where 100.000 boulders were put out into a 5-hectare area on the seafloor. The NBS benefits include better protection and restoration of coastal ecosystems through the promotion of the growth of marine vegetation, which in turn creates habitat and food for other species and sequesters and stores carbon. The new reefs act as substrate for organisms to settle onto and as a base of a diverse ecosystem, thus promoting ecosystem functions. As a result of this NBS, increased biomass of cod and crustaceans have been recorded. The project can also benefit climate change mitigation and flood risk reduction. Although this could not be quantified, macroalgae are thought to play a role in carbon storage and wave dampening (Oppla, 2022).

Restoration of eelgrass beds

In **Sweden**, NBS projects focus on restoration and conservation of marine habitats including management and restoration of eelgrass beds and assessment of underwater vegetation to reduce coastal erosion. One example of a marine NBS project describes the restoration of eelgrass habitat by sand-capping at the Swedish West Coast. Eelgrass has a stabilizing effect on the sediment, and in areas where eelgrass has been lost, a negative feedback of increased sediment resuspension and turbidity, causing poor light conditions, can prevent the regrowth of eelgrass. By covering the sediment with a layer of sand and gravel about 10 cm thick, this NBS project could help stabilize the sea floor, reduce sediment resuspension, and create favourable conditions for renewed eelgrass growth in areas of historical eelgrass beds. Around 1.800 tons of sand and gravel were placed on top of the sediment and eelgrass transplanted onto it in order to fix the sediment, reduce erosion, reduce eelgrass loss and enhance biodiversity. Subsequently, 80.000 shoots of eelgrass were planted on the area in 2022 and will continue to be monitored in coming years (Infantes, 2021).

Restoration of salt marshes

In **Finland**, there were no projects described with the term 'nature-based solutions' in the coastal and marine ecosystems in the grey literature. However, there are endeavours to restore coastal areas, especially those that are important to commercial fish stocks. Examples of restoration and rehabilitation projects to improve water quality and fish stocks in Finnish coastal regions include "flada" (type of salt marsh) habitat restoration, which often consists of cutting down swamp vegetation (notably *Phragmites* reed beds) in areas that used to be bays with flowing water. The aims of these projects are usually to restore the spawning grounds of local fish and to improve water quality, and they include physical restoration and fish roe monitoring to document the success. One example is at Backfladan (2019–21) on the west coast. Measures included clearing and opening a brook with an excavator to improve water flow and to support fish movements to their spawning areas. Further examples at Solbackfladan and Ytteröfladan (2018–21) on the south coast, included measures such as reed-cutting to increase water flow and to improve conditions for perch spawning. In a similar project, "glo" (another salt marsh type) restoration, stones were dug out and moved within a brook channel, to improve water flow and support brook fish at Sibbo Byträsket, southern Finland, during 2020–21 (Kuningas et al., 2021).

Expected and obtained biodiversity gains and other societal benefits from coastal/marine NBS

Although it is impossible to quantify the net biodiversity gains of marine and coastal NBS at this point, due to them rarely being described as such, the societal benefits from the implementation of coastal and marine NBS are manifold. Successful coastal and marine NBS benefit society in terms of ecosystems services and increased marine life in general. They help to filter water, produce more usable stocks and produce more oxygen as well as storing carbon which helps with the greenhouse gas emission problems. Another societal benefit of, for example, near shore vegetation is disaster risk reduction in terms of wave dissipation which protects shorelines and flood risk reduction which protects coastal housing and infrastructure.

Specific barriers/challenges/issues related to implementing coastal/marine NBS in the Nordics

In the Nordic Countries, coastal and marine NBS are used in a variety of ways. Although some countries use NBS more substantially in the coastal and marine area than others, the concept is gaining a foothold in the Nordics and will further develop. One crucial aspect in the future development of coastal and marine NBS is the need for cooperation across borders for synergies and sharing of expertise, but also because in some cases, effects in the larger marine systems need cooperation of multiple states and actors. In addition to working together across national states, local stakeholder engagement is crucial for successful NBS implementation and maintenance in the coastal and marine space. Ocean literacy and marine education programmes should be integral parts of marine NBS in order to engage those local stakeholders and communities.

4.4.3 Forest

Forests cover about 85% of land area in Finland, 70% in Sweden, 35% in Norway, 13% in Denmark and 2% in Iceland. According to these numbers, the Nordic countries are drastically different from each other: in terms of share of global wood production and export, Finland and Sweden both comprise about 10%, whereas Norway adds only 1% and Denmark and Iceland are near zero. Protected forests – that are completely or partly beyond reach of forest management – can be classified according to the strictness of protection (Ekström and Hannerz, 2020). After pooling different levels of protection, 35% of Icelandic forests are to some degree protected, whereas the percentages are about 17 for Denmark and Finland, and about 7 for Norway and Sweden (ibid.). If only the two strictest categories are considered, Iceland has none, whereas Denmark has about 1%, Norway and Sweden have about 6%, and Finland has about 12% (ibid.). Therefore, most forests in the Nordic countries are managed and thus targets for NBS actions.

Overview of societal challenges addressed with NBS in a forest context

The term 'nature-based solutions' is not used in the Nordic forestry context. Instead, the language of forest professionals contains terms such as restoration, rehabilitation, nature-oriented management, continuous-cover forestry and close-to-nature forestry and all these contain elements of NBS. In Nordic managed forests, four NBS are commonly and widely applied: protection of the most valuable forest micro-sites (key biotopes), retention of living trees in varying amounts and spatial arrangements (including so-called continuous-cover forestry), preservation of existing and creation of new deadwood (mostly as artificial snags or "high stumps"), and controlled burning of logging slash or standing trees, i.e., prescribed burning (Gustafsson et al., 2019b; Koivula and Vanha-Majamaa, 2020; Koivula et al., 2022; Routa and Huuskonen, 2022). These operations are expected to benefit threatened and rare species and thus help to reverse the long-lasting negative trends of populations of these species. However, some of the methods also maintain forest quality for recreation and other outdoor activities, particularly retention approaches. Hence, these are commonly applied in or near urban forests, parks and recreational areas. Generally, these methods address important societal challenges related to the well-being of citizens, maintenance of ecosystem services and fulfilment of political goals set to maintain biodiversity. Retention also presumably contributes to carbon storage, thus contributing to climate actions Most methods are easily adopted into forestry operations and their application does not cause societal conflicts, apart from prescribed burning, which can sometimes present a potential hazard and must therefore be applied very cautiously.

NBS are used side by side with economic and timber-production targets. The minimum requirements for the NBS described below are based on national forest and nature-conservation acts and on criteria for forest certification,[16] but any forest owner can voluntarily take additional measures. These measures have been intensely studied in Finland, Sweden and Norway since the 1980s, and the role of fire considerably longer, whereas only scattered publications exist from Denmark or Iceland. The NBS methods, apart from the quite rarely applied burning, are commonly used in most Nordic managed forests.

Examples of typical forest NBS in the managed forests of Nordic countries

Here, we assess the biodiversity pros and cons of these NBS methods. We focus on replicated experiments (Appendix 9.2). Compared to case trials or ad hoc sampling of impacted forests, experiments allow a considerably more powerful assessment of the factors of interest. They have, e.g., untreated reference sites and can account for site-to-site variation through replication of treatments. There are many tests of NBS implementation done in managed Nordic forests. However, as biodiversity

16. Examples of forest certification initiatives: www.fsc.org; www.pefc.org

responses in these case trials are seldom assessed, and they usually lack control and replication, we limit this review to top-quality experiments, except in the case of key biotopes, which are NBS by definition. In a focused search of scientific literature of NBS management actions in forest ecosystems in the Nordics we identified altogether 22 experiments that assess NBS. We put emphasis on resource-specialists and red-listed species because these species require modifications to survive in managed forests, whereas generalists or open-habitat associated species thrive in current conditions. Due to space limitations, below we refer only to major reviews or meta-analyses that assess NBS. For those interested in individual studies, consult the references in the cited works.

In the late 1980s or early 1990s several experiments were established to compare clear-cutting with various retention-forestry methods, with retention levels of sometimes up to 50–70%, by removing the largest trees relatively evenly (selection cutting) or in patches of varying sizes (gap cutting). During those decades' low retention (up to a few m3/ha of trees) was justified as being an economically viable way of maintaining recreational values and biodiversity. More recently, continuous-cover forestry has gained plenty of interest among foresters and forest owners who wish to retain the recreational and aesthetic values of their forests, and to support biodiversity. These methods have been studied for several decades from the points of view of regeneration and timber production, but biodiversity research in these forests began only in the early 1990s.

Key biotopes

Key biotopes are considered more valuable in tree-structural features (notably large-sized trees and coarse deadwood) and red-listed species than conventional commercial forests. Based on more than 20 papers (summarized in Koivula et al., 2022), this pattern holds for Sweden and Norway, but not for Finland. Key biotopes in the latter country are demarcated mostly as being on average much smaller than one hectare, and much larger in the other countries, and selection criteria differ between countries (Timonen et al., 2011). Small patches are vulnerable to edge effects, and their species populations face elevated risks of extinction due to small population sizes (ibid.). Ecological research suggests that management operations are not desirable at these sites to preserve their natural characteristics of old trees and dead wood. However, coniferous trees may be removed from grove habitats, or prescribed burning applied in pine-heath forests, to maintain characteristic microclimatic conditions and populations of habitat specialists (Koivula et al., 2022). Also, the effective area of a key biotope can be increased by treating adjacent forests with selection or gap cutting instead of clear-cutting, or by clustering retention trees right next to the key biotope patch (ibid.).

Retention-tree strategies

Even single trees retained in clear-cuts or gap harvested stands (Figure 12) are useful for some shade-requiring species (Koivula et al., 2022). If trees are retained in patches larger than 0.5 hectares, they can efficiently preserve microclimatic conditions and most closed-forest species (ibid.). However, considerably larger retention patches should be established for some lichens and mosses occupying large living and dead trees to secure their presence at a site (ibid.). Moreover, if the aim is to secure the populations of red-listed species, very large (diameter at breast height about 40–50 cm or larger) living trees should be retained permanently at all stages of forest management, thus taking care of the continuous availability of such trees (and, in turn, dead trees) for species that tend to be poor dispersers (ibid.). Deciduous trees of low economic value and large and old deciduous trees are particularly important retention trees, yet it is still quite common for a forest owner to routinely remove these in various management operations. Such trees support epiphytic species and, after tree death, also such deadwood-dependent species that do not occupy conifers (Hyvärinen et al., 2019; SLU Artdatabanken, 2020; Norwegian Biodiversity Information Centre, 2021). Deciduous trees are also an important part of the dynamics and structure of coniferous forests (Koivula et al., 2022). Furthermore, they can contribute to mitigating the effects of climate change on conifer-dominated forests.

Figure 12. Retention trees in a gap-harvested stand.
Photo: Matti Koivula, Luke.

Wooded water-edge ecosystems and spruce mires have been extensively studied in the retention context and are important for moist-habitat specialists and deadwood-dependent species (Koivula et al., 2022). To mitigate micro-climatic alterations and changes in water-associated species communities, 25–35 m wide and unharvested or only selectively cut shelterbelt forests (buffer zones) should be applied (Hasselquist et al., 2021; Koivula et al., 2022). This is in line with the above-suggested retention-patch size. Moreover, deciduous trees and deadwood should be retained in forest streams and spring habitats for biodiversity (ibid.). Within managed landscapes, most mires host less deadwood than they would in pristine conditions, and may often also be harvested, although their retention in forestry operations is mandatory (see national forestry legislation). This is at least partly unintended, as harvesting is often done in winter months when such patches are not visible because of snow cover. Retention of water-edge and mire habitats greatly supports policy goals on increasing deadwood and securing biodiversity.

Continuous-cover forestry benefits species that require tree cover and shade. However, per se it does not produce structural features required by red-listed species, such as very old trees and large-sized dead wood (Koivula et al., 2022; Routa and Huuskonen, 2022). This is because in principle it is just another way of producing timber – an alternative for even-aged forest management based on regeneration through clear-cutting – and targets the largest trees in a stand. Clearly, if preservation of red-listed species is a priority, these features must be taken care of separately. Continuous-cover forestry may be a better option than conventional forestry in terms of nutrient leaching and carbon balance (Routa and Huuskonen, 2022).

Deadwood preservation and creation
The amount of deadwood in Nordic managed forests is more than an order of magnitude lower than in pristine conditions, to which deadwood-dependent species are evolutionarily adapted (2–10 versus 20–150 m3/ha, depending on site type and geographic region; Koivula et al., 2022). One consequence is that hundreds of deadwood-dependent species are in Nordic red lists. Research evidence on the importance of deadwood for red-listed species has in the present millennium led to general recommendations of retaining deadwood to support deadwood-dependent species. However, in Finland these have not led to improvements of nature-oriented management, on the contrary: many NBS levels have declined since the late 1990s (Siitonen et al., 2020).

To support these species and to maintain the dead wood in managed forests, retention of existing dead wood in harvesting operations may be the most cost-efficient way (Koivula et al., 2022). In regeneration operations, the operator should avoid harvesting large-sized dead trees for energy-wood purposes and to use only light – if any – top-soil preparation (ibid.). The amount of dead wood remaining after logging may be a more important determinant of deadwood-dependent species than the applied logging method. Living retention trees are part of the cycle, as they die at some point contributing to the deadwood continuity at a site. Assuming that deadwood continuity would be secured only by using living retention trees during each 100-years cycle, the volume of 10 m3/ha of deadwood in the long term would require a permanent retention of about 30 m3/ha of living trees (Koivula et al., 2022). Deadwood can be added into managed forests through, e.g., setting aside key biotopes, retaining trees permanently at regeneration sites, creating artificial snags and applying prescribed burning, but also by increasing the logging-rotation length, and reducing the use of precommercial thinning (ibid.).

Artificial snags – 3–5 m tall high stumps left in clear-cuts – are common in Nordic managed forests. They were first applied in the early 1990s without evidence for them supporting deadwood-dependent species, but since then research has shown them to be useful particularly for beetles, including many red-listed species (Koivula et al., 2022). However, for saproxylic fungi – commonly referred to as polypores –

except for the base parts of the trees, they rapidly become too dry (ibid.). For these fungi, downed large trees appear to be more important substrates.

Prescribed burning

Forest fires used to be a key determinant of the dynamics and structure of Nordic forests, whereas at present they are scarce events, despite some major fires in Sweden in the past few years (Gustafsson et al., 2019a). Consequently, fire-driven habitats and fire-dependent species have become rare. Burned wood supports fire specialists and, as fire weakens and kills trees, hundreds of saproxylic species (Koivula et al., 2022). From a biodiversity perspective, instead of conventional prescribed burning, it would be good to burn large stands with relatively abundant large trees (Figure 13). This is because the amount of burned wood appears to be an important determinant of biodiversity benefits (ibid.). However, as this action might be controversial, particularly nearby human settlement, it could be applied in a few tailored fire-continuity areas (Lindberg et al., 2020).

Figure 13. Prescribed-burn and deadwood creation experiment in the municipality of Hämeenlinna, Southern Finland.
Photo: Matti Koivula, Luke.

Expected and obtained biodiversity gains and other societal benefits from forest NBS

Nordic boreal forests harbour several tens of thousands of species. Hundreds of years of rather intense forest use has made more than 10% of these species threatened with extinction. As a response to this trend, the EU Biodiversity Strategy requires member countries to act to "put Europe's biodiversity on the path to recovery by 2030". Common generalists and open-habitat species thrive in Nordic managed forests, whereas species that are dependent on forest structural features that are scarce because of forestry require targeted actions to survive. These features include large-sized living and dead trees and certain kinds of forest habitat, such as post-fire forests. Nature-based solutions are intended to increase these features, notably retention of living trees, logging methods other than clear-cutting, retention and production of deadwood and prescribed burning.

Specific challenges related to implementing forest NBS in the Nordic countries

The above-reviewed research indicates that biological responses to NBS vary among different groups of species, and that many effects are detectable for more than ten years, possibly over the full rotation of 60–90 years. However, the research-covered time scale has thus far been relatively short because the assessed NBS, with the notable exception of fire, have been applied in forest management only for about 20–30 years. Research covering 50–100 years since treatments would be crucial for assessing, for example, extinction debt caused by forestry, or the full decay process of artificial snags. Moreover, we cannot say whether, e.g., continuous-cover forestry applied 60–80 years ago has cumulative effects on biodiversity compared to documented impacts of once applying selection or gap cutting in relatively old stands. The above-reviewed NBS methods are commonly applied in all Nordic countries, and even if they are not all equally studied in all the countries, they nevertheless support red-listed species and bring back elements of pristine forests into managed woodlands. Thus, despite the above-listed shortcomings in available research data, NBS measures are very useful from ecological, social and (with some reservations) economic viewpoints. It is a matter of debate, then, whether the economic investments in NBS in managed forests should be allocated to purchasing forests for permanent protection.

4.4.4 Freshwater

The Nordic countries have a long history of applying different types of measures in freshwater ecosystems to provide solutions for societal challenges and to tackle eutrophication (e.g., Uusi-Kämppä et al., 2000; Syversen, 2005; Berninger et al., 2012; Hoffmann et al., 2020). Overall, the historically adopted solutions have many similarities to nature-based solutions, but two important aspects have simply been disregarded when comparing to the NBS definition of IUCN (IUCN, 2020). Firstly, clear and measurable biodiversity conservation outcomes are rarely identified, benchmarked or periodically assessed. Secondly, the benefits provided are rarely tracked or measured. No adaptive management is considered after implementation of the measures, so opportunities to facilitate continuous learning about system-wide processes and adapting it to possible changes are lost. However some key actions undertaken in freshwater ecosystems in the Nordic countries will be treated as NBS in the following text.

Overview of what societal challenges can be addressed with NBS in a freshwater context

Streams, lakes, peatlands and wetlands are among the most threatened ecosystems globally. There is clear scientific evidence for a dramatic decline in their biodiversity and of impairments to both provisioning and regulatory services in freshwater ecosystems (Reid et al., 2019). These services include, for instance, the provision of clean drinking water, irrigation water for agriculture and water for energy production, as well as their capacity to mitigate floods and droughts, and to regulate sediment transport. Over the last decades, the capacity of freshwater ecosystems to provide solutions for eutrophication and climate changes has been increasingly acknowledged. These solutions mainly build on the reinstatement of the natural processes which characterize healthy freshwater ecosystems, either alone or in combination with the instalment of more technical structures that can stimulate these processes even further to maximize ecosystem service benefits. (Figure 14).

Figure 14. **Example of a constructed wetland (subsurface flow) for water purification in the open land.** Left: the constructed wetland just after implementation. Right: two years after implementation (DK).
Photo: Carl Christian Hoffmann, Aarhus University.

Examples of typical freshwater NBS in the Nordics

Typical NBS in freshwater ecosystems in the Nordics have addressed eutrophication of aquatic ecosystems and more recently climate change. They include measures that can be seen as restorative interventions such as wetland restoration and afforestation as well as measures that are to some extent engineered in order to stimulate processes required to enhance ecosystem service benefits (see Table 6). For example, in some areas, to stimulate water purification, drainage pipes can be disconnected at the field margin and drainage water diverted into the riparian zone in lateral distribution pipes running parallel to the stream to create anoxic conditions in the whole area to support denitrification. Another example is to let the drainage water pass a sedimentation pond followed by sequential zones of one-meter-deep open water and 0.3 m deep shallow vegetation zones before the outlet to the stream. All the listed measures in Table 6 have been applied in the Nordic region and target nitrogen pollution with some of them also targeting phosphorus.

In addition to water purification, restoration of freshwater ecosystems can also stimulate carbon sequestration and in cases with high contents of organic matter within the soil, such as in degraded peatlands, restoration can also play a pivotal role in reducing the emission of climate gases to the atmosphere. All types of peatlands share the common characteristic of being water-saturated up to the soil surface, at least seasonally, with actively forming peat (Hristov, 2004). Globally only about 3%

of the land area is peatland (De La Haye et al., 2021), however, Iceland and Finland stand out with a proportion of 20% or 30%, respectively (The Soil Conservation Service of Iceland, 2021d). In Iceland, it has been estimated that degraded peatlands can contribute to about 70% of anthropogenic greenhouse gas emissions (The Soil Conservation Service of Iceland, 2021c) and rewetting is therefore increasingly considered as an NBS for climate regulation (Aradóttir, et al., 2013). In Denmark, for example, 20,000 ha of low-laying soils are to be rewetted within the coming years to reduce climate gas emission. Following rewetting, peatland may successfully continue to store carbon (De La Haye et al., 2021). In addition to climate regulation, peatlands also provide many other important services, such as mitigating floods and droughts (De La Haye et al., 2021; The Soil Conservation Service of Iceland, 2021d) and peatlands are also able to purify water and to reduce the risk of wildfires in areas with abundant peatlands (De La Haye et al., 2021).

Furthermore, NBS that involve reconnecting the stream with its floodplain can also reduce flooding of downstream areas, as well as increase resilience to drought, since a disconnection of drainage pipes will halt water within the system. A very short summary of the main solutions is provided in the Table 6 below, as well as key references for each of the NBS.

Expected and obtained biodiversity gains and other societal benefits from freshwater NBS

For most of the listed NBS in Table 6, only very limited evidence exists for long term effects on biodiversity. This reflects that biodiversity conservation targets have rarely been identified, benchmarked or assessed in these projects. Also, the measures can be combined in different ways and depending on how and where, the benefits for biodiversity can vary. For some of the NBS, biodiversity benefits can be expected at the local scale, in terms of increases in the number of species that can be found. NBS which create increased areas of open water and/or altered hydrological conditions can lead to more birds visiting an area and higher numbers of insects, but at the same time these benefits cannot always be interpreted as improvements for biodiversity. For further discussion on this see chapter 5.1.2.

Specific barriers/challenges/issues related to implementing freshwater NBS in the Nordics

For some of the listed NBS in Table 6, their implementation may involve a risk of phosphorus loss to the aquatic environment, resulting from high soil availability due to former land use practices. This loss may continue for years, and measures to reduce this loss are therefore increasingly applied together with the NBS. These include harvesting of biomass before introducing the NBS (e.g., cattail, reed), topsoil removal and placement of phosphorus retention filters in wetland outflows, but for the moment these measures are still in the testing phase as pre- or accompanying measures to the NBS. Sedimentation of particulate phosphorus during inundation of floodplains can also be a measure that reduces phosphorus loss to lakes and coastal areas. At the same time high loads of phosphorus will affect the development of the vegetation within the floodplain and hence negatively affect the biodiversity outcome of the NBS.

Table 6. Overview of different types of measures that can be seen as nature-based solutions for water purification, flood and drought mitigation and climate regulation in Nordic countries (a detailed description can be found, for example in Hoffmann et al. 2020). Some of the measures are purely restorative interventions while others have in-built technical solutions to enhance the NBS functioning. The extent of technical solution as part of the NBS is scaled from low to high (1–3) in the table.

NBS type	Main societal challenge(s) addressed	Main approach	Technical solution (scale 1–3)
Restoration of wetlands, including peatlands swamps and fens	Water purification; Flood and Drought mitigation; Climate regulation	Reestablishment of the natural hydrology. Most projects are undertaken in riparian wetlands and degraded peatlands by disconnecting drain pipes and ditches. Furthermore, in cases where there is an adjacent river that is channelized, a re-meandering of the reach is often carried out	1
Re-establishment of shallow lakes and ponds	Water purification, Climate regulation		1
Saturated buffer zones	Water purification;	Drain pipes are disconnected at the field margin and drainage water is diverted into the riparian zone in a lateral distribution pipe running parallel to the stream. From the lateral pipe, the drainage water infiltrates the riparian soil towards the stream, which will cause the riparian soil to become saturated and consequently create anoxic conditions that support denitrification	2
Integrated buffer zone	Water purification	A pond is established where soil particles present in drain water can settle out combined with a sub-surface flow infiltration zone planted with vegetation	3
Subsurface flow constructed wetlands	Water purification	Different design solutions have been studied, including both vertical and horizontal flow, as well as the establishment of a storage pond in front of the bioreactor (e.g., wood chips as substrate) to mitigate peak flow events and increase sedimentation	3
Surface flow constructed wetlands	Water purification	Drainpipes are disconnected and the drainage water passes through a sedimentation pond, followed by sequential zones of one-meter-deep open water and 0.3 m deep shallow vegetation zones before the outlet to the stream	3
Drain water irrigation	Water purification	Drainpipes are disconnected at the field margin and the drain water is distributed over a gutter inserted at the soil surface or via distribution channels placed parallel to the stream	3

4.4.5 Urban and artificial NBS

Urbanisation is an ongoing trend in the Nordic countries. In 2022 more than 30% of the Nordic population lived in cities[17] and this trend continues. Both urbanization trends, urban sprawl as well as densification, have come with challenges. While urban sprawl expands the city area and converts natural areas and ecosystems into urban areas, densification can lead to reduction in area, deterioration and overuse of green areas inside the city, so that they cannot longer fulfil their required natural functions such as temperature regulation, absorption of rainfall or provision of recreational areas for inhabitants. In recent years many Nordic cities increasingly started using NBS to restore these natural functions and to accommodate their inhabitants needs for enough green space.

Overview of what societal challenges can be addressed with NBS in a Nordic urban context

Nordic cities have similar challenges they wish to address with NBS to other cities around the globe. NBS in Nordic cities are mainly used in the context of climate change adaptation (stormwater management, temperature regulation) and for recreational, cultural and aesthetic purposes. But they are also used for climate change mitigation (reduction of greenhouse gases), reduction of environmental pollution (in water and air), noise attenuation, restoration of biodiversity, and to foster public health and improve social cohesion (Amorim et al., 2021; Hautamäki, 2021). It was, for example, shown in a modelling study how urban green infrastructure can mitigate summer heat in Oslo, Norway (Venter et al., 2020b). Gentin et al. (2018) showed how NBS can actively be used for a better integration of foreign immigrants into Nordic societies. Urban NBS are also used in Nordic cities for stormwater management and in the context of soft mobility i.e., by creating green cycling and pedestrian routes.

Examples of typical urban/artificial NBS in Nordic cities

We define urban/artificial NBS as those which are conserved, restored or newly constructed within the built-up zone of cities. We do not consider NBS outside the built-up area as falling into this category, even though they can be of great importance for a city for recreational purposes. Urban and artificial NBS are quite diverse. They include NBS and ecosystems belonging to the previously described categories (forest, agriculture, freshwater and coastal/marine), but also completely artificial NBS or mixed natural and technical/engineered NBS (hybrid NBS). Examples of urban NBS used in Nordic cities include

Reopened urban stream stretches: Mainly triggered by the EU Water Framework Directives requirement of a good environmental status of all water bodies, Nordic cities started reopening and restoring stream stretches, which were often due to hygienic reasons buried in underground pipes or channelized. Restoration to a "close to natural state" is often difficult, given that other urban land-uses or infrastructure tends to occupy the space where the streams flowed historically. In practice, stream reopening projects are often adapted to their urban surroundings i.e., concerning the

17. Data from Nordic Statistics database. https://www.nordicstatistics.org/areas/demography/

area and vegetation chosen for the riparian zone (see for example Figure 15). Reopened stream stretches can retain more nutrients (Baho et al., 2021) and forested riparian zones provide an important habitat for fish if the water quality is good enough (Kupilas et al., 2021). A study from Helsinki showed large support of city inhabitants and even a willingness to financially contribute to urban stream reopening projects (Sarvilinna et al., 2017).

Constructed wetlands, dams and ponds in cities (for an example see Figure 15, left picture) are similar to their freshwater NBS counterparts in more rural areas (see Table 6), but often smaller in size. Vegetation and organisms have often to withstand more harsh environmental conditions due to pollution from road runoff, waste disposal or higher frequencies of recreational use by city inhabitants.

Parks, cemeteries and allotment gardens (urban green spaces) are public spaces partly or fully covered by vegetation, which can be considered as NBS as they fulfil a societal function (recreation, religious purpose, food production) benefit biodiversity and often deliver several ecosystem services in addition (Breuste et al., 2013). The importance of urban green spaces for recreation during and after the COVID-19 pandemic was i.e., well documented for Oslo (Venter et al., 2020a; 2021).

Street trees are acknowledged as an important urban NBS to adapt and mitigate climate change, improve citizens health and well-being and to contribute to urban sustainability (Salmond et al., 2016). Copenhagen (State of Green, 2015) and Oslo (Oslo municipality, n.d.) have tree planting programs, Helsinki has its own urban tree policy (Peurasuo, et al., 2014), Reykjavik will "strengthen the cultivation of trees within the urban area and (..) strengthen city forestation at the peripheral region" (City of Reykjavik, 2014) and Stockholm has developed special skeletal soil, which helps to avoid challenges street trees often face like lack of space for roots, shortage of water, nutrients and oxygen (Swedish Portal for Climate Change Adaptation, 2018).

Low-impact development measures (also called sustainable urban drainage structure or blue green infrastructure) consists of smaller NBS interventions, which have the main purpose to reduce, delay and clean stormwater runoff. These type of NBS include raingardens, vegetated swales, tree pitches and green roofs. Besides stormwater management these NBS also deliver a range of other benefits such as recreation, climate regulation, carbon sequestration (Prudencio and Null, 2018). A prominent example from the Nordic countries is the Augustenborg neighbourhood in Malmö, Sweden, where 90% of all stormwater is treated in NBS such as green roofs, ponds, dams and raingardens, improving the water quality and reducing the amounts of water, which are later released into the North Sea (Bayulken et al., 2021).

Artificial urban NBS are often connected to grey infrastructure i.e., to roofs or underground pipes. The properties of these NBS are often enhanced by using artificial materials i.e., activated carbon or biochar can partly replace soils in raingardens to increase their capacity to absorb pollutants (Wai, 2022; Yue et al., 2018). In Nordic cities along the coasts, artificial NBS would also extend to the coastal or marine areas, which are often heavily influenced by urban development leading to polluted runoff, building activities in the coastal zone and morphological changes in coastline and sea bottom. These artificial urban NBS include i.e. artificial reefs and replanting of seagrass meadows.

What is special with urban NBS is, that they are – due to the limited space available in densely populated cities – often designed in a manner such that they can address multiple urban challenges simultaneously i.e., handling stormwater, regulating temperature and providing additional benefits such as aesthetically appealing recreational areas, fostering public health and well-being. Often the installation of additional facilities (i.e., benches, lights at night, toilets, playgrounds) are required to make urban NBS attractive and accessible for a diverse urban population and thus to increase their societal benefit (see examples in Figure 16).

Figure 15. Examples for urban NBS enhanced by facilities to make them more attractive for users. Left: Pond for water cleaning as part of a reopened river stretch amended with steppingstones. Right: urban green area with a barbecue facility; both examples are from Oslo (NO).
Photo: Isabel Seifert-Dähnn, NIVA.

Figure 16. Enghaven park i Copenhagen (DK) can be considered as an NBS.
In case of heavy rainfall parts or the whole park can be flooded and will function as a large retention basin for stormwater; The sports ground on the right picture is considered as a park amenity, which provides recreational values and works as retention basin – it should not be considered as stand-alone NBS.
Photo: Ingvild Skumlien Furuseth, NIVA.

Expected and obtained biodiversity gains and other societal benefits from urban/artificial NBS

When it comes to biodiversity gains from NBS in cities, an often-raised argument is that NBS provide additional habitat and are therefore positive for biodiversity. However, biodiversity gains are not obtained automatically, they depend to a large degree on how species are selected and managed in an NBS. Are native or non-endemic species chosen? Sometimes non-endemic species can better withstand the harsh living conditions in an urban environment, such as drought conditions in summer, temporary flooding after heavy rainfall, salt runoff in winter, limited root space for vegetation and freezing-thawing dynamics. Is the NBS artificially planted or is it naturally recolonized? Is regular maintenance work done such as cutting and weeding or is rewilding the main management strategy? There is also a scale aspect to this: Many urban NBS are fragmented and lack connectivity to other NBS. Or they lack continuity, such as urban streams, which are disrupted by culverts where streets are crossing, and other fish migration barriers occur. This fragmentation leads to situations where full biodiversity benefits cannot be obtained.

Specific barriers/challenges/issues related to implementing NBS in urban areas

One challenge for mainstreaming urban NBS in Nordic cities is the limited availability of space. In general, urban NBS are often smaller than similar NBS types in the countryside, as they compete for space with other land-uses, especially in fast growing cities like the Nordic capitals. This limited availability of space often applies to public areas. One solution used by Nordic city governments is regulations, which influence the management of NBS on private areas. These regulations include i.e., restrictions on felling large private trees, area sealing restrictions on private properties or use of performance-based green area indicators as used in Stockholm, Malmö (Sweden) and Oslo (Norway). Another solution to the space problem is to design urban NBS so that they fulfil multiple purposes. However, a downside of this multi-functionality is that the NBS do/may not perform all functions as expected or that there is a trade-off between different NBS functions. For example, raingardens are meant to store, infiltrate and clean stormwater, but they are sometimes also used as dog walking areas depending their location and design. Dog excrement poses a challenge for the plants and can also lead to hygienic problems. A related but opposite challenge arises when artificial NBS do not have the required environmental quality to allow for the hoped-for recreational use (see example in Figure 17). Another challenge is the "over-use" of urban NBS by humans, which can, for example lead to damaged vegetation from walking, sport activities or barbecues. Vegetation in urban NBS is also challenged by the harsh environmental conditions which exist in cities, such as salt-runoff in winter, frequent change between freezing-thawing conditions, physical stress due to humans or vehicles. Urban NBS should be designed in a way to withstand these pressures, but this is often not so easy. So, it is very important to perform regular monitoring of urban NBS, to learn for future projects and adapt the NBS management if needed (see also chapter 5.1.1).

Figure 17. Example from Oslo (Norway): Bjerkedalen park was a combination of a stream reopening project embedded in a park area. Left: small, reopened stream stretch. Right: At the lower end of the park a small beach was created, but the current water quality does not allow for bathing or playing with the water. *Photo: Isabel Seifert-Dähnn, NIVA.*

5 Challenges and opportunities for mainstreaming NBS in Nordic Countries

NBS governance and implementation is an area that is currently advancing rapidly. At the same time, there are still several challenges, but also opportunities, for using NBS to mitigate and adapt to climate change, protect biodiversity and ensure human well-being (Seddon et al., 2020). Here we summarize some important challenges and opportunities for mainstreaming NBS in the Nordics. The summary is based on discussions within the project group, outcomes of the stakeholder workshop, and existing grey and scientific publications. One of most recent and comprehensive summaries is done by the EU project NetworkNature, which mapped knowledge gaps, research and innovation needs related to the mainstreaming of NBS in Europe. This was done through an online consultation, an in-person workshop and a review of the existing European policy documents and publications. The project has also established a NBS knowledge gaps database.[18] Many of the challenges NetworkNature found were location specific, but they identified four broad categories of challenges and knowledge gaps, which were related to the governance of NBS, the technical design of NBS, evaluation of NBS and capacity building for NBS (El Harrak and Lemaître, 2022b). In another recent study Seddon et al. (2020) conclude that the three main financial and governance challenges for NBS were: measuring the effectiveness of NBS (see also chapter 5.1.1), mobilizing investments for the implementation of NBS and overcoming governance challenges. Many of these challenges are also found the Nordic countries and are described in more detail in the following chapters.

5.1 Natural-scientific and technical knowledge gaps

5.1.1 Shortcoming of long-term monitoring and evaluation of NBS

In order to evaluate the efficiency of NBS measures across ecosystems and land use types, it is essential to have evidence of the specific impacts of NBS. We also need information on how NBS can deliver multiple benefits, and yet such information is still fragmented (Brink et al., 2016). The European Commission has developed a system for assessing and mapping ecosystem services in support of the EU Biodiversity Strategy, including economic valuation (Maes et al., 2016). Regarding the evaluation of the impact of NBS, important questions remain regarding how to assess NBS within and across societal challenges (Raymond et al., 2017). Most studies on the impact of NBS are limited to single cases, limited in terms of the impacts considered or have focused too much on a specific type of NBS (Dumitru et al. 2020). Most attention so far has focused on assessing the environmental aspects

18. Network Nature NBS knowledge gaps database. https://networknature.eu/nbs-knowledge-gaps

and impacts of NBS without paying enough attention to economic, social and health impacts (Brink and Wamsler, 2018; Raymond et al., 2017).

It is therefore clear that the evidence base for NBS implementation needs to be more comprehensive, include evaluations across larger spatial and temporal scales and contain monitoring and evaluation schemes that also comprise participatory planning and governance processes (Raymond et al., 2017). This may include evaluations of how existing data and methods can be used to assess the impact of NBS, as well as the development and collection of new data, indicators and methods. It is necessary to create an evidence base for the climate zones relevant in the Nordic countries, as the transferability of results from other climatic zones or societies is limited. The spatial scale aspect is especially important as the scale of NBS implementation significantly affects its potential to deliver the expected outcome (Andersson et al., 2017). In the planning and implementation phase of NBS, it is also necessary to take into consideration current environmental and climate change, which can undermine the integrity of ecosystems and thus the capacity of NBS to deliver on expected outcomes (Calliari et al., 2019). A number of frameworks have been developed to assess NBS: the integrated valuation of a nature-based solution for water pollution control (Liquete et al., 2016); the assessment of the effectiveness and co-benefits of nature-based solutions in urban areas including NBS design, implementation and evaluation (Raymond et al., 2017); the assessment of the regulation of urban run-off (Zölch et al., 2017); a more general a 'dynamic' assessment framework explicitly incorporating climate change (Calliari et al., 2019).

The NetworkNature EU initiative on NBS summarizes the main gaps related to evaluation of NBS. We lack "monitoring as performance and evaluation of NBS over time and socio-ecological context, or around the development of tools and methodologies for systemic evaluation" (El Harrak and Lemaitre, 2022a). Knowledge gained from such schemes is not well shared with stakeholders and other user groups. One further aspect when evaluating NBS is that "ecosystems are living entities and, as such, evolve over time as the result of natural processes or in response to external pressures" (Calliari et al., 2019) and this needs to be taken into consideration. Similar concerns were also raised in the S-ITUATION Nordic stakeholder workshop, where participants discussed:

- lack of initial data for proper project planning
- missing monitoring and assessment schemes for evaluating NBS
- lack of information regarding the effects of NBS on social and ecological values across different spatial scales and on long-term effects

According to IUCN criteria 7, NBS should be regularly monitored and evaluated throughout the NBS life cycle in order to enable adaptive NBS management based on evidence and iterative learning for future NBS projects (IUCN, 2020). Based on the experience of the S-ITUATION consortium members, this is unfortunately seldom done in the Nordic countries.

5.1.2 Lack of a clear definition of biodiversity net-gain

The term biodiversity means different things to different people. For some, biodiversity is valued for the variety of species and the beauty of the habitats, while others give special value to ecosystem-service benefits that biodiversity can provide for us humans. However, an evaluation of biodiversity net-gain when implementing an NBS requires a well-founded understanding of the current state of the ecosystems concerned. The baseline assessment needs to be broad enough to characterize ecological state, drivers for ecosystem loss and options for net improvements, making use of both local knowledge and scientific understanding where possible (IUCN, 2020).

Biodiversity is a clear focal point when it comes to the implementation of an NBS. But the evaluation of biodiversity outcomes is complex. For example, the scale considered can be quite decisive when assessing biodiversity developments. That is, at the very local scale, the implementation of an NBS may cause an increase in species richness, but the species that establish may be common species and the extent of biodiversity net gain at the regional or global scale may not be as high as if the increase in species richness was due to less common species. Similarly, if the increase in species richness also includes non-native species, an evaluation of the net benefit for biodiversity will not be straightforward. It can also be that the NBS is implemented in a way that potentially conflicts with the protection of species of special interest (e.g., species listed in the annexes to the Habitats Directive; IUCN red listed species).

An evaluation of biodiversity net gain will also be context-dependent and different outcomes may be seen in different regions in the Nordic countries even when applying similar NBS. For example, rewetting of former wetlands may, depending on the origin of the water and nutrient contents (drainage water, surface water, groundwater) increase local species richness if the areas involved are low productivity areas like poor fens, whereas the opposite may occur in areas with a higher productivity, as an increase in nutrient availability in the area can favour nitrophilous species leading to the competitive exclusion of other species. In the latter case, there will probably be no biodiversity benefits in implementing the NBS. The different scales that are relevant to consider when predicting effects of a specific NBS on biodiversity, the context dependency of the NBS for the biodiversity outcome, and the fact that species are valued differently, as reflected in national and international legislation, with some species being of special interest (e.g., species listed in the annexes to the Habitats Directive; IUCN red listed species), may all add confusion or discrepancies in the evaluation of biodiversity net gain following implementation of an NBS (Figure 18).

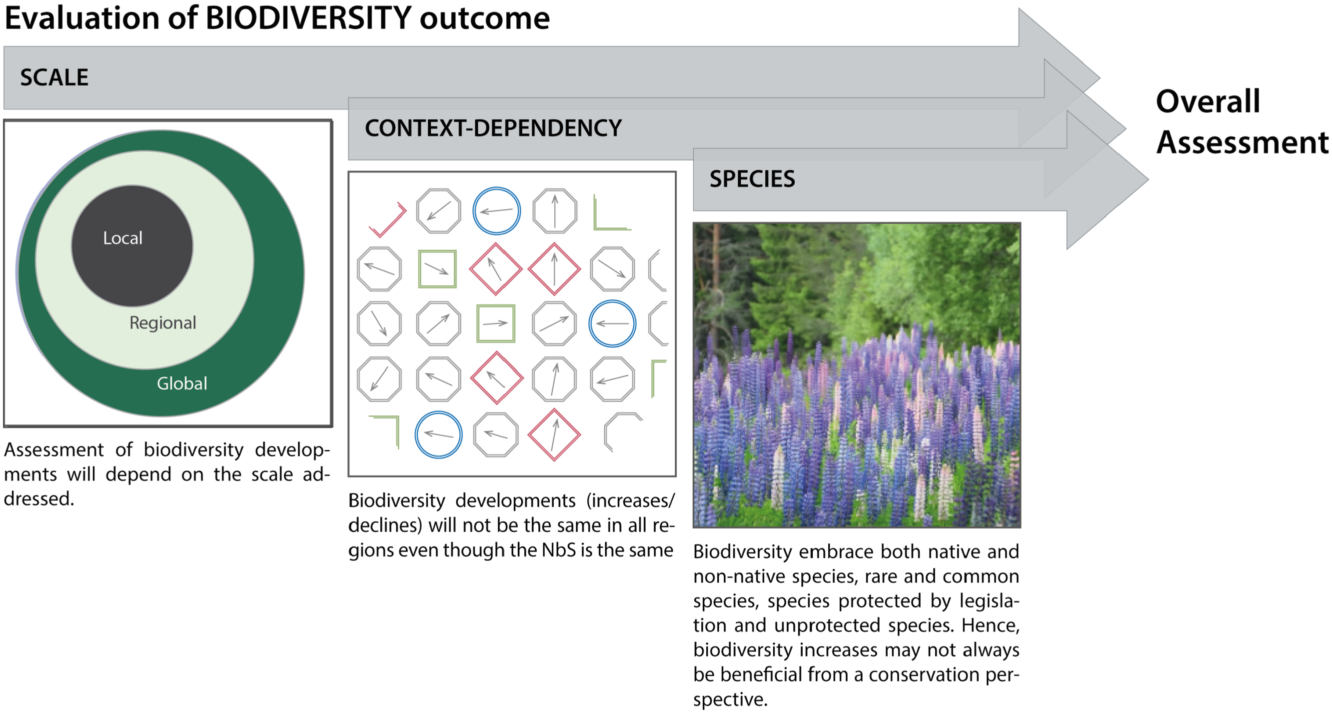

Figure 18. The figure displays some key aspects to consider when evaluating biodiversity net gain in relation to the implementation of an NBS.
Source: own elaboration AU.

NBS also have substantial potential for biodiversity benefits by increasing habitat connectivity, but the evidence for this remains limited (Pettorelli et al., 2021). In Figure 18, we advocate that both scale, context-dependency and target species should be considered when setting biodiversity targets when implementing an NBS, and, equally importantly, that well-adjusted monitoring should be a mandatory element to follow-up biodiversity outcomes both on the short- and long term. For each NBS, the types of targets may differ; for example, the target could be to increase the percentage of restored ecosystem area, the return of a locally extinct species, or an increase in the number of species in a given area. Ideally, an NBS should improve biodiversity over the long term and across a large area by linking conservation efforts with more specific NBS measures within the region. Provided that monitoring takes place, this link will also enable us to learn more of the efficiency of different NBS that can be applied in the Nordic region and to assess the effectiveness of these and eventually adapt further management to halt biodiversity declines.

5.1.3 Technical and ecological knowledge gaps of practitioners

The design and construction, but also operation and maintenance of well-functioning NBS, that provide multiple benefits is often difficult. There are still evidence gaps for certain types of NBS and certain functions they are expected to fulfil or benefits to be obtained (Viti et al., 2022; Chausson et al., 2020). Local landscape and ecosystems conditions such as climate, soil type, slope and vegetation influence the performance of NBS (Seddon, 2022). It makes, for example, a substantial difference for the infiltration capacity if a raingarden is located on sandy (fast draining) or on loamy (slow/not draining) soil. For forest ecosystems, there is little knowledge on the benefits of NBS in forest types other than the most common spruce- and pine-dominated heath forests (e.g., groves, semi-open forests, young phases following natural disturbance). Scale is another important issue to consider when planning an optimal NBS, as different types of benefits might unfold differently at small or large scales or at a certain distance from the NBS intervention (Hutchins et al., 2021). For forest NBS it remains unclear how the regional application of NBS would unfold in comparison to local application and what would be the effects of a higher density of NBS interventions in comparison to those that are usually applied in commercial forests. There is also a trade-off between the multiple functions of NBS. It is unlikely that they can all perform optimally, simultaneously (El Harrak and Lemaître, 2022a). It is therefore difficult to predict exactly the effect or outcome of an NBS and to standardize NBS as can be done with technical solutions (Dorst et al., 2022). This might undermine the trust in NBS, in comparison to engineered and technical solutions. In addition, there is also often a higher competence in relation to technical or engineering solutions in the relevant public agencies, than on NBS, which leads to a preference for these types of solutions (sometimes called "grey solutions") and inhibits increased adoption of NBS. To overcome this problem of technological path dependency, academic scholars suggested targeted NBS-education for infrastructure professionals (Davies and Lafortezza, 2019). If NBS are implemented, they might also underperform, because entrepreneurs lack expertise for the optimal design of NBS. The lack of regular and long-term monitoring and evaluation of NBS (see chapter 5.1.1) inhibits iterative learning on how to overcome NBS construction weaknesses in the future, which is also suggested by IUCN criterion 7 (IUCN, 2020).

Tools like the IUCN guidance book for their Global Standard for Nature-based Solutions (IUCN, 2020) are very complex to use and resource demanding, but they take several of the challenges mentioned in this chapter into account. An increased application of such tools could thus help to overcome those challenges in the future, but this would require adequate training of business, practitioners and stakeholders in the field of NBS.

5.2 Economic shortcomings

There are several shortcomings in relation to socio-economic aspects of NBS, which are interwoven with other shortcomings. One main issue is the lack of scientific and economic evidence on the costs and benefits of NBS over their complete lifetime. This results in incomplete cost-benefit analysis of NBS, so that NBS interventions cannot properly be compared with alternative, more technical solutions. A lack of information about the performance of NBS arises due to the lack of regular monitoring (see also chapter 5.1.1), but also because the observed benefits are not monetized and integrated into economic valuation and accounting methods (i.e., natural capital accounting), something which could facilitate the acquisition of funding (Toxopeus and Polzin, 2021). Regular monitoring is important, as the stream of benefits might change over time and it might take a while before the natural functions of NBS which generate their benefits are fully established. Concerning costs, it is important to consider, not only the implementation costs of NBS, but also the accruing management and maintenance costs over time. For example, minor urban NBS often require maintenance of their vegetation (i.e., pruning, fertilizing, irrigation), which could lead to higher management and maintenance costs than technical solutions like pipes or dams. On the other hand, any adjustment of NBS could be easier and less costly than modifications of technical solutions. The lack of information and uncertainty about costs and benefits of NBS makes it difficult to calculate reliable revenue streams and to develop appropriate investment plans for NBS (Swann et al., 2021), which leads to a second shortcoming.

The second shortcoming is the lack of coordinated public and private funding for NBS. The diversity of benefits which NBS can deliver to different actors or societal needs, should ideally also be reflected by a certain breadth of funding sources. Currently this is not or only very seldom the case. Public funding for urban NBS often only relies on the budgets of water or park agencies ignoring i.e., the public health benefits of NBS or their contribution to less stormwater flooding, which is a clear benefit for the insurance sector. If evaluation of NBS does not include major benefits as well as co-benefits, the cost-benefit analysis is likely to underestimate the value of an NBS to the society. The acquisition of a larger spectrum of investors could potentially lead to the implementation of both larger as well as more NBS. A better coordination of public funding would probably help to solve the challenge of low private-sector engagement in financing NBS (Dorst et al., 2022). Another funding gap is that long-term operation and maintenance costs are currently often not funded as part of NBS project grants, but only the implementation of the NBS. There is consequently a risk of deterioration of NBS over time if sufficient funding for operation and maintenance is lacking.

The mentioned shortcomings are also underlined by comments given by Nordic stakeholders during workshops held in November 2021:

- It is difficult to assess costs and benefits of NBS in comparison to more traditional technical solutions. We need better cost-benefit analysis for NBS. NBS can address several problems simultaneously and not only one problem at a time, but this is not reflected sufficiently in current cost-benefit analysis as not all benefits are considered. In addition, current cost-benefit analysis of NBS often do not properly consider the long-term benefits of NBS. This leads to the wrong impression that NBS are more expensive.
- NBS investors must be able to "see" the revenue they get from investing in NBS instead of other solutions.
- Incentive systems might help to mainstream NBS and to attract more private investment.
- Water companies should become creative on how to use their funds (mainly derived from water fees). What is important is that they deliver their services (producing drinking water, cleaning wastewater) and NOT how they do it. So, they should become more proactive in testing NBS instead of only building underground infrastructure.
- There is low awareness and knowledge about NBS among the general public. To get more funding from the government, more awareness about NBS is needed. If politicians are going to promote specific solutions like NBS, this needs to be understood by the general public and their voters.

- It is important to develop NBS in small steps instead of doing the revolution at once.

5.3 Regulatory, governance and policy challenges

Governance structures related to NBS (in a broad sense) differ between the different Nordic countries. This difference relates to how landowner rights have been defined (e.g., which environmental factors need to be considered and how local or national authorities can gain access to private land for planning and implementation purposes) and how different environmental concerns (climate adaptation, biodiversity protection and water quality) have been included in the legislation. It also depends on differences in governance culture between the countries and the ability of the culture and the legislative and policy structure to pick up and handle new environmental issues.

A frequently mentioned governance gap is the lack of ability to develop cross-sector structures which support the placement and implementation of NBS. This includes cross-sector policy between, for example, urban areas and agricultural land or between cities and coastal land. This absence of structures also concerns the lack of models for monetary transfer between private and public organisation or between different public bodies (such as for example the development of climate adaptation measure upstream – downstream). New financial structures could also include the development of different types of offset markets. However, when developing such markets, it will be essential to consider the distributional effects across actors and scales.

Another issue with the current governance structures is that the NBS are supposed to provide multiple benefits, but governance structures are developed to handle one environmental problem at the time. In addition, the knowledge base for assessing the efficiency of these solutions is spread across disciplines, which makes the understanding of the complete range of co-benefits more difficult. If the full range of benefits are not estimated and considered when implementing NBS, it may lead to sub-optimal placement, despite good governance structure. For example, the placement of wetlands for nutrient reduction financed under the Common Agricultural Policy (CAP) has led to wetlands in areas with less productive land and lower nutrient levels and thus these wetlands are less efficient in removing nutrients compared to wetlands placed in more productive land, exposed to higher nutrient levels. Moreover, due to the division of governance system into sectors there is, in many cases, no clear structure for how to balance different societal interest in relation to the NBS. Questions related to the ability of NBS to contribute to biodiversity are therefore dependent on how each country sets up its governance structures as well as the educational background, experience and expertise of the persons working with the question.

For large NBS, implemented to decrease environmental pressures crossing several administrative boundaries, it is difficult to balance large-scale landscape planning issues with the provision of benefits at the local scale. There is also a need to develop governance structures that can assess and understand social conflicts between local level and landscape level contributions of NBS. In addition, NBS are natural features that will evolve and develop over time. Therefore, NBS solutions need to be managed in an adaptive manner and NBS maintenance needs to include both appropriate monitoring structures as well as proper maintenance plans, covering longer time periods. The current governance structure (law, policy and organizational setup) is not designed to take into consideration the relation between financing structures and solutions across sectors.

In the regulatory setting, only Norway specifically mentions the term NBS. However, most Nordic countries have regulations and policies related to NBS. These policies include the protection and restoration of protected areas, environmental concerns in agriculture and forestry as well the need to take climate change into consideration when developing future cities. Based on our assessment it was not possible to say, if the existing regulatory framework of the Nordic countries are "supportive enough" to mainstream NBS. However, a strong regulatory framework explicitly mentioning NBS will support the long-term development of NBS and ensure that the necessary collaboration between relevant actors happens. The potential to mainstream and implement more NBS depends on the ability to transform the current governance system to jointly handle the co-benefits of NBS as well as to implement NBS in an efficient (administrative and implementation costs) and effective (environmental and social benefits) manner. During the Nordic stakeholder workshops held in November 2021, regulation, governance and policies related to NBS were addressed by the stakeholder in the following way:

- The use of NBS is not something new, but may, if implemented more frequently, need to include new ways of planning and working.
- If an adaptive understanding of the benefits and co-benefits of the NBS was built into the implementation system, this knowledge could serve as a basis for the development of a carbon offset market in the Nordic countries.
- Methods for assessing the benefit and effectiveness of NBS must be transparent and able to convince different actors (e.g., local governments) to choose NBS over traditional or engineered solutions, such as for example underground pipes, concrete walls and to some extent also dams. Such methods also need to be able to incorporate uncertainty and the fact that there is frequently a time lag between the implementation of NBS and their full effect.
- Overcoming legislative hurdles and barriers e.g., when planning flood protection measures in river basins where nature is protected by the EU Habitats Directive.
- There is lack of funding for the implementation of NBS.
- Fewer top-down governmental structures could be beneficial for the development and implementation of NBS schemes. Politicians have become more aware about the NBS concept during the last few years. There are ongoing discussions related to opening up for more coordination activities at the regional scale, which could facilitate and improve placement and implementation of NBS.

5.4 Weak stakeholder collaboration

According to the fifth IUCN-criteria, NBS should be based on inclusive, transparent, and empowering governance processes (IUCN, 2020). This implies that stakeholders should be engaged in the planning and the design of the NBS. This is especially relevant in urban areas, which can be dense with overlapping interests. Stakeholder collaboration includes interactions between private landowners and the local authority, as well as local citizens. Participatory events have, if well performed, a possibility to enhance local engagement and commitment to the implementation of NBS.

Despite this, there are few examples of NBS projects that have involved stakeholders to a large extent; both in the Nordic countries and internationally. In the anthology 'The Eco-city Augustenborg', Martinez Avila et al. (2021) described the stakeholder participation efforts in the regeneration project Eco-city Augustenborg in Malmö; one of the most famous NBS project (focusing on stormwater management) in Sweden. In the study, there were several examples of events where stakeholders were engaged, but there was limited evaluation of how this engagement influenced the result of the project or how stakeholders experienced their involvement in the project. There was limited evidence for organisational learning about how to perform stakeholder collaborations or how that learning should be mainstreamed into the general municipal organisation. These results are in line with previous research, demonstrating a general lack of knowledge on how to create, use, and institutionalize collaborative structures to facilitate NBS implementation (Brink and Wamsler, 2018). In addition, it has also been shown that citizen engagement can lead to undesirable outcomes where the interest of different groups of stakeholders are opposed to each other (Wamsler et al., 2019) One influencing factor, is that collaborative structures are frequently not institutionalized as an integral part of NBS policies but rather seen as something that is expected to happen by itself, with no allocated funds to keep up the participatory processes. Another factor is "silo thinking" of local and regional authorities, as different administrative units with separate responsibilities, budgets, and foci, making the work towards joint goals more difficult.

Stakeholder collaboration is identified as an important part of the planning, design and management of NBS and recommended in the global standard for NBS developed by IUCN (2020). Therefore, more attention (for example, during the compulsory development of strategic documents or during the concrete implementation phase) and money (support where collaborative efforts are needed) have to go to efforts including stakeholders. Yet another and interlinked problem is that the participatory processes that are developed during the funding and implementation phase of a project are dissolved at the project end. NBS need long lasting governance and policy structures to ensure that a solid participatory culture can be developed, which in the long run, could support maintenance and facilitate the development of an adaptive management culture (Leader processes within the Common Agricultural Policy, as well as water councils and flood groups within the water framework directive, as well as the Flood directive, can be given as examples of where such collaborations have been nurtured over time.)

6 Conclusions

With the increasing uptake of the NBS concept in science, policy and practice, there is a corresponding need to ensure that the concept is clearly understood, communicated and implemented in a manner that assures that societal challenges are solved, and biodiversity as well as climate adaptation and mitigation are supported. The multi-functional character of NBS provide a great opportunity to address several societal and environmental challenges simultaneously. This also makes governance, implementation and operation of NBS challenging as many stakeholders' needs must be considered and weighed and a strong cross-sectoral cooperation is required. A strong reason to implement NBS is that it focuses simultaneously on bending the curve of biodiversity loss, the adaptation and mitigation to climate change and has a strong focus on societal challenges.

In this project, we found that Nordic researchers are increasingly being involved in European and national research projects, thus actively contributing to and providing a stronger evidence-base related to NBS. This includes the multi-functionality of the societal benefits and biodiversity gains, design and implementation, governance, cost-effectiveness, financing, monitoring and management, as well as other aspects related to NBS. These academic activities should be sustained in order to strengthen the position of the Nordic countries as role models for successful NBS implementation.

In most Nordic countries NBS are used for climate change mitigation and adaptation and to reduce pollution, in addition to having biodiversity benefits. Other societal challenges are addressed to a lower extent but also have great potential. Successful examples of NBS projects exist in all Nordic countries and across all ecosystems considered in this report. Our policy assessment showed that the Nordic countries have different approaches and policy frameworks for planning and implementing NBS, which is reflected in the existence of clearly defined governance structures and the availability of supporting materials to implement NBS. All Nordic countries have legislation, strategies and policies that support conservation, restoration and sustainable use of NBS, although they do not necessarily call it NBS, but use related terms. These legislations, strategies and policies have room for improvement in all Nordic countries and the lack of coordination and understanding between the sectors working to implement NBS needs to be addressed when doing so.

We find similar challenges and opportunities for mainstreaming NBS in the Nordics as have been found in other countries. These include shortcomings in monitoring and evaluation of NBS, lack of clear definitions and targets for biodiversity gains, technical and ecological knowledge gaps, economic difficulties related to cost-benefit assessment and funding mechanisms of NBS, regulatory, governance and policy challenges as well as potential for improvements to the participatory processes for stakeholders. Our key messages and future recommendations to overcome these challenges can be found in the next chapter.

7 Key messages and recommendations

This report provides a status overview on how NBS are implemented in the Nordics and concludes with the following key messages and recommendations for the future mainstreaming of NBS:

Clear political prioritization is needed to mainstream NBS into policy and practice: NBS can address the climate crisis, biodiversity loss and other societal challenges (e.g., food security, water security, human health, disaster risk reduction, social and economic development) simultaneously. The use of NBS should therefore be made a clear political priority. There is a need to actively steer away from "business-as-usual" i.e., from choosing technical or engineering solutions without considering and, when possible, implementing NBS. If possible, the conservation and protection of important ecosystems should be prioritised as the first solution. If this is not possible; one should consider restoration actions or implementation of other types of NBS. Sustainable use and management of ecosystems should always be prerequisites for NBS.

Appropriate institutional structures, procedures and policy instruments at all governance levels are essential to facilitate the implementation of NBS: To advance the implementation of NBS, there is a need to transform institutional structures and policy instruments across different sectors. The use of NBS should always be considered in land-use planning and decision-making; and NBS should be made the preferred solution, if multi-functionality and cost-effectiveness, in comparison to alternative solutions, can be proven. We recommend that:

- The current policy framework for NBS in the Nordics is assessed in detail concerning the effectiveness and efficiency of its policies. For example, assessing the outcome of the Norwegian governmental planning guideline which requires public authorities to consider implementing NBS and to justify why it was not chosen, if this is the case.
- New institutional structures to support adaptive management need to be developed. With climate change and changes of other environmental conditions over time, ecosystem management practices must become adaptive, otherwise it will not be possible to capture the envisaged NBS benefits, especially in a future with climate change.
- The use of participatory approaches and stakeholder involvement must be required in all NBS projects to ensure a just and equitable transition to a sustainable future. It is fundamental to strengthen collaboration and communication with stakeholders and the NBS communities from the local to the transnational level. This includes facilitating cooperation between researchers and public authorities.
- We need better ways to cooperate across agencies, sectors and policy levels. It is unlikely that one main actor will transform the whole policy and management system. To enable a transition to preferential use of NBS, a shift in mindset and

more cross-sectoral and agency cooperation is needed.

Better funding structures for NBS are needed: In order to have more funds for NBS available in the future, the consortium suggests the following:

- National legislation should be reviewed and adapted in order to eliminate funding structures that hinder the adoption of NBS i.e., because technical solutions are required by law. A prominent example are water and sewage fees or stormwater fees, which can only be used for NBS to a very limited extent.
- More "creativity" is needed to find new business models for cross-sectoral and public-private financing mechanisms for individual NBS projects. Examples from other countries (i.e., UK, US) should be reviewed and considered for adoption in the Nordics. Public funds might be needed to reduce the investor risk in public-private co-funding projects, especially in cases with high scepticism towards NBS solutions.

Common standards and guidelines are needed to support increased adoption of NBS including setting clear biodiversity targets: The use of a global standard such as the one developed by IUCN could help to solve several of the challenges related to NBS implementation. Such a standard can serve as an instrument to raise awareness and provide a holistic picture of the interwoven aspects to be considered for successfully implementing NBS. Public authorities should consider whether it would be useful to define minimum requirements concerning the quality of NBS interventions including requirements for biodiversity benefits and considering the cost-effectiveness of the solutions.

Long-term monitoring and more comprehensive cost-benefit evaluation of NBS is required: There is a general lack of information about baseline conditions, current and future conditions and effects of implemented NBS, which makes adaptive management difficult. Sufficient before and after data is key to reduce uncertainty about NBS effectiveness, define minimum requirements for quality and performance of NBS interventions, increase the trust in NBS, attract funding and enable adaptive management of NBS. Related to this issue, it is necessary to:

- Set clear and measurable targets (including biodiversity targets) during the planning phase and clarify what should be achieved by each implemented NBS. Such targets could be related to funding mechanisms.
- Include holistic cost-benefit assessments considering as many types of NBS and ecosystems as possible. This includes as many benefits as possible and should take into consideration changes to nature over time (naturally and through human interventions).
- Develop tools, standards, and platforms for how the monitoring and assessment of individual NBS outcomes can be linked to existing environmental or economic monitoring structures (i.e., natural capital accounting and the future EU restoration law).

The knowledge base in all phases of NBS projects needs to be strengthened: Knowledge-sharing is vital in the planning, design, implementation, operation and evaluation of NBS. The results and knowledge should be broadly communicated, targeting key actors (e.g., policymakers, decision-makers, researchers, and practitioners). A major driving force for this need is that there is generally a higher competence available for technical solutions among relevant actors. This is the case for both the private and public sector, which has created an implementation bias towards technical solutions. Therefore, it is necessary to:

- Further strengthen research on NBS to reduce uncertainties and improve the knowledge-base on performance, costs, benefits, disbenefits, trade-offs, and implementation, of different NBS types and ecosystems. This includes implementation under varying environmental and climatic conditions
- Facilitate iterative learning from innovative NBS pilot projects and on NBS adaptive management, allowing also for failures
- Acknowledge and consider traditional and indigenous knowledge
- Increase NBS education on all education levels from elementary schools to higher education and integrate it in the curricula of technical and engineering professions such as civil engineers
- Support capacity-building among practitioners, especially in municipalities and eventually link that to NBS education initiatives
- Creating support arenas for exchanging knowledge and experiences about NBS across the Nordics and globally, taking the Nordic NBS programme as a point of departure
- Develop more practical guidance on how to plan, design, implement and operate NBS

8 References

Albrecht, M., Kleijn, D., Williams, N. M., Tschumi, M., Blaauw, B. R., Bommarco, R., ... Sutter, L. (2020). The effectiveness of flower strips and hedgerows on pest control, pollination services and crop yield: a quantitative synthesis. *Ecology Letters,* 23(10), 1488–1498. https://doi.org/10.1111/ele.13576

Almassy, D., Pinter, L., Rocha, S., Naumann, S., Davis, M., Abhold, K., & Bulkeley, H. (2018). *Urban nature atlas: a database of nature-based solutions across 100 European cities*. Report of H2020 Project Naturvation. Retrieved from: https://una.city/

Amorim, J. H., Engardt, M., Johansson, C., Ribeiro, I., & Sannebro, M. (2021). Regulating and cultural ecosystem services of urban green infrastructure in the Nordic countries: A systematic review. *International Journal of Environmental Research and Public Health*, 18(3), 1219.

Andenæs, E., Time, B., Muthanna, T., & Kvande, T. (2022). Risikorammeverk for blagronne tak. Klima2050. SINTEF Community. Retrieved from: https://www.sintefbok.no/book/index/1317/risikorammeverk_for_blaagroenne_tak

Andersson, E., Borgström, S. & McPhearson, T. (2017). Double insurance in dealing with extremes: ecological and social factors for making nature-based solutions last. In Nature-based solutions to climate change adaptation in urban areas. In: Kabisch, N., Korn, H., Stadler, J., Bonn, A. (eds) *Nature-Based Solutions to Climate Change Adaptation in Urban Areas. Theory and Practice of Urban Sustainability Transition*s. Springer, Cham. https://doi.org/10.1007/978-3-319-56091-5_4

Aradóttir, Á. L., Petursdottir, T., Halldorsson, G., Svavarsdottir, K. & Arnalds, O. (2013). Drivers of Ecological Restoration: Lessons from a Century of Restoration in Iceland. *Ecology and Society,* 18(4). doi:10.5751/ES-05946-180433

Arkema, K. K., Griffin, R., Maldonado, S., Silver, J., Suckale, J., & Guerry, A. D. (2017). Linking social, ecological, and physical science to advance natural and nature-based protection for coastal communities. *Ann. NY Acad. Sci,* 1399(1), 5–26.

Baho, D.L., Arnott, D., Myrstad, K.D., Schneider, S.C. & Moe, T.F. (2021). Rapid colonization of aquatic communities in an urban stream after daylighting. *Restor Ecol*, 29, e13394. https://doi.org/10.1111/rec.13394

Balian E., Berhault A., Eggermont H., Lemaître F., von Korff Y., & Young J.C. (2016). *Social innovation and nature-based solutions.* EKLIPSE/EPBRS/BiodivERsA Joint Foresight Workshop: Brussels, 6–7 December 2016. Workshop Report. Retrieved from: https://www.eklipse-mechanism.eu/apps/Eklipse_data/website/EKLIPSE_WP4-WebReport_June2017.pdf

Bayulken, B., Huisingh, D. & Fisher, P. M. J. (2021). How are nature-based solutions helping in the greening of cities in the context of crises such as climate change and pandemics? A comprehensive review, *Journal of Cleaner Production*, 288, 125569, ISSN 0959-6526. https://doi.org/10.1016/j.jclepro.2020.125569

Berninger, K., Koskiaho, J & Tattari, S. (2012). Constructed wetlands in Finnish agricultural environments: Balancing between effective water protection and multi-functionality. *Journal of Water and Land Development* 17(1). DOI:10.2478/v10025-012-0029-5

Breuste, J., Haase, D. & Elmqvist, T. (2013). Urban Landscapes and Ecosystem Services. In *Ecosystem Services in Agricultural and Urban Landscapes* (eds. S. Wratten, H. Sandhu, R. Cullen and R. Costanza). https://doi.org/10.1002/9781118506271.ch6

Brink, E. & Wamsler, C. (2018). Collaborative Governance for Climate Change Adaptation: Mapping citizen–municipality interactions. *Environmental Policy and Governance* 28, 82–97. https://doi.org/10.1002/eet.1795

Brink, E., Aalders, T., Ádám, D., Feller, R., Henselek, Y., Hoffmann, A., Ibe, K., Matthey-Doret, A., Meyer, M., Negrut, N. L. & Rau, A. L. (2016). Cascades of green: A review of ecosystem-based adaptation in urban areas. *Global environmental change,* 1(36), 111–23. https://doi.org/10.1016/j.gloenvcha.2015.11.003

Calliari, E., Staccione, A., & Mysiak, J. (2019). An assessment framework for climate-proof nature-based solutions. *Science of the Total Environment*, 656, 691–700. https://doi.org/10.1016/j.scitotenv.2018.11.341

Capobianco, V. E. (2020). Nytt verktøy kan bidra til at flere velger naturbaserte løsninger for å redusere skred og erosjonsfare langs elver og bekker. VANN, 3. Retrieved from: https://vannforeningen.no/wp-content/uploads/2020/10/Capobianco.pdf

Carstensen, M. V., Hashemi, F., Hoffmann, C. C., Zak, D., Audet, J., & Kronvang, B. (2020). Efficiency of mitigation measures targeting nutrient losses from agricultural drainage systems: A review. *AMBIO*, 49(11), 1820–1837. https://doi.org/10.1007/s13280-020-01345-5

Chausson, A., Turner, B., Seddon, D., Chabaneix, N., Girardin, C. A., Kapos, V., ... Seddon, N. (2020). Mapping the effectiveness of nature-based solutions for climate change adaptation. *Global Change Biology*, 26(11), 6134–6155. https://doi.org/10.1111/gcb.15310

City of Reykjavík (2014). *Reykjavík Municipal Plan 2010-2030*. Department of Planning and Environment. Retrieved from: https://reykjavik.is/sites/default/files/reykjavik-municipal-plan-2010-2030.pdf

Cohen-Shacham, E., Andrade, A., Dalton, J., Dudley, N., Jones, M., Kumar, C., ... &

Renaud, F. G. (2019). Core principles for successfully implementing and upscaling Nature-based Solutions. *Environmental Science & Policy,* 98, 20–29. https://doi.org/10.1016/j.envsci.2019.04.014

Cohen-Shacham, E., Walters, G., Janzen, C. & Maginnis, S. (2016) *Nature-based solutions to address global societal challenges.* Gland, Switzerland: IUCN. Retrieved from: https://portals.iucn.org/library/sites/library/files/documents/2016-036.pdf

Constantin, J., Mary, B., Laurent, F., Aubrion, G., Fontaine, A., Kerveillant, P., & Beaudoin, N. (2010). Effects of catch crops, no till and reduced nitrogen fertilization on nitrogen leaching and balance in three long-term experiments. *Agriculture Ecosystems & Environment*, 135(4), 268–278. doi:10.1016/j.agee.2009.10.005

County Administrative Board of Skåne (2020). *Assessment of underwater vegetation to reduce coastal erosion. Effect of eelgrass (Zostera marina) on wave attenuation at Lomma Bay*. Report, February 2020. Retrieved from: https://northsearegion.eu/media/14696/assessment-of-underwater-vegetation-in-reducing-coastal-erosion.pdf

County authority of Rogaland. (2021). *Naturbaserte løsninger for klimatilpasning: En prosessveileder for arbeid med naturbaserte løsninger for klimatilpasning i Rogaland*. Rogaland fylkeskommune. Retrieved from: https://www.rogfk.no/vare-tjenester/planlegging/veiledning-i-planarbeidet/natur-klima-og-miljo/naturbaserte-losninger/

Davies, C. & Lafortezza, R. (2019). Transitional path to the adoption of nature-based solutions. *Land use policy, 80*, 406–409. https://doi.org/10.1016/j.landusepol.2018.09.020

De La Haye, A., Devereux, C., & van Herk, S. (2021). *Peatlands Across Europe: Innovation & Inspiration. State of the Art & Guide to Next Steps*. Barcelona: Bax & Company. Retrieved from: https://www.decadeonrestoration.org/publications/peatlands-across-europe-innovation-and-inspiration

Dinesen, L., Petersen, A.H. & Rahbek, C. (2021). *Synergy in conservation of biodiversity and climate change mitigation in Nordic peatlands and forests - Eight case studies*. IPBES in Denmark; Center for Macroecology, Evolution and Climate; Nordic Council of Ministers. Retrieved from: https://pub.norden.org/temanord2021-510/temanord2021-510.pdf

Dorst, H., van der Jagt, A., Toxopeus, H., Tozer, L., Raven, R., & Runhaar, H. (2022). What's behind the barriers? Uncovering structural conditions working against urban nature-based solutions. *Landscape and Urban Planning*, 220, 104335. https://doi.org/10.1016/j.landurbplan.2021.104335

Dumitru, A., Frantzeskaki, N., & Collier, M. (2020). Identifying principles for the design of robust impact evaluation frameworks for nature-based solutions in cities. *Environmental Science & Policy,* 112, 107–116. https://doi.org/10.1016/j.envsci.2020.05.024

EEA – European Environment Agency (2021). *Nature-based solutions in Europe: Policy, knowledge and practice for climate change adaptation and disaster risk reduction.* EEA Report No 1/2021, Luxembourg: Publications Office of the European Union. Retrieved from: https://www.eea.europa.eu/publications/nature-based-solutions-in-europe

Ekström, H. & Hannerz, M. (2020). *Nordic forest statistics 2020.* Wood Resources International LLC & Silvinformation AB. Retrieved from: https://nordicforestresearch.org/wp-content/uploads/2021/03/Nordisk-skogsstatistik.pdf

El Harrak, M. & Lemaître, F. (2022a). Draft European Roadmap for Research and Innovation on Nature-based Solutions. NetworkNature. Retrieved from: https://networknature.eu/sites/default/files/images/NetworkNature_Draft_EU_RI_Roadmap_on_NBS.pdf

El Harrak, M. & Lemaître, F. (2022b). *Deliverable 3.5. Report on practical, research and innovation needs.* NetworkNature project. Retrieved from: https://networknature.eu/sites/default/files/uploads/networknature-d35report-practical-research-and-innovation-needs.pdf

European Commission (2015). *Towards an EU Research and Innovation policy agenda for Nature-Based Solutions & Re-Naturing Cities. Final Report of the Horizon 2020 Expert Group on 'Nature-Based Solutions and Re-Naturing Cities'.* Brussels, Belgium: Directorate-General for Research and Innovation. Retrieved from: https://op.europa.eu/en/publication-detail/-/publication/fb117980-d5aa-46df-8edc-af367cddc202

European commission (2022). *Nature-based solutions research policy.* Retrieved from: https://research-and-innovation.ec.europa.eu/research-area/environment/nature-based-solutions/research-policy_en

Fine Foods Íslandica (2022). *Seaweed Cultivation and Food Production in Breiðafjörður.* Retrieved from: https://finefoods.is/our-story-1

Fitzgerald, H., Palmé, A., Aronsson, M., Asdal, Å., Bjureke, K., Endresen, D., Göransson, M., Hyvärinen, ... & Wind, P. (2021). *The Nordic Priority Crop Wild Relative Dataset.* doi:10.6084/m9.figshare.5688130.v3

Fitzgerald, H., Palmé, A., Asdal, Å., Endresen, D., Kiviharju, E., Lund, B., Rasmussen, M., Thorbjörnsson, H., & Weibull, J. (2019). A regional approach to Nordic crop wild relative in situ conservation planning. *Plant Genetic Resources: Characterization and Utilization 2019*, 17, 196–207, http://dx.doi.org/10.1017/S147926211800059X

Gentin, S., Chondromatidou, A. M., Pitkänen, K., Dolling, A., Præstholm, S., & Pálsdóttir, A. M. (2018). Defining nature-based integration - perspectives and practices from the Nordic countries. Reports of the Finnish Environment Institute 16/2018. Retrieved from: https://www.slu.se/globalassets/ew/org/centrb/fu-one-health/publikationer/sykera_16_2018_report_defining-nature-based-integration.pdf

Global Crop Diversity Trust (n.d.). *Crop Wild Relatives and Climate Change Adaptation.* Retrieved from: https://www.cwrdiversity.org/project/cwr-and-climate-change-adaptation/

Gustafsson, L., Berglund, M., Granström, A., Grelle, A., Isacsson, G., Kjellander, P., Larsson, S., Lindh, M., Pettersson, L. B., ... & Mikusiński, G. (2019a): Rapid ecological response and intensified knowledge accumulation following a north European mega-fire. *Scandinavian Journal of Forest Research*, 34(4), 234–253. https://doi.org/10.1080/02827581.2019.1603323

Gustafsson, L., Hannerz, M., Koivula, M. et al. (2019b) Research on retention forestry in Northern Europe. *Ecol Process 9 (3).* https://doi.org/10.1186/s13717-019-0208-2

Hart, C. (1998). *Doing a literature review: releasing the social science research imagination.* London: SAGE publications.

Hasselquist, E. M., Kuglerová, L., Sjögren, J., Hjältén, J., Ring, E., Sponseller, R. A., Andersson, ... Laudon, H. (2021). Moving towards multi-layered, mixed-species forests in riparian buffers will enhance their long-term function in boreal landscapes. *Forest Ecology and Management 493*, 119254. https://doi.org/10.1016/j.foreco.2021.119254

Hautamäki, R. (2021). From Forest Towns to Nature-Based Solutions: In Search of Finnish Urban Nature. In *Green Visions: Greenspace Planning and Design for Nordic Cities.* Nilsson, K., Weber, R. & Rohrer, L. (eds.). p. 64–85.

Hoffmann, C. C., Zak, D., Kronvang, B., Kjaergaard, C., Carstensen, M. V., & Audet, J. (2020). An overview of nutrient transport mitigation measures for improvement of water quality in Denmark. *Ecological Engineering*, 155, 105863. https://doi.org/10.1016/j.ecoleng.2020.105863

Holmer, M., Flindt, M., Valdemarsen, T., Kristensen, E., & Walløe Thorsen, S. (2016). Når naturen vender tilbage – Gyldensteen Kystlagune. *Aktuel Naturvidenskab 1,* 2016. Retrieved from: https://aktuelnaturvidenskab.dk/fileadmin/Aktuel_Naturvidenskab/nr-1/AN1-2016gyldensteen.pdf

Hristov, I. (2004). *Wetland Types and Classifications.* Central European University. Retrieved from: http://www.personal.ceu.hu/students/03/nature_conservation/wwddetail/Types_classif.html

Hutchins, M. G., Fletcher, D., Hagen-Zanker, A., Jia, H., Jones, L., Li, H., ... Yu, S. (2021). Why scale is vital to plan optimal nature-based solutions for resilient cities. *Environmental Research Letters*, 16(4), 044008.

Hyvärinen, E., Juslén, A., Kemppainen, E., Uddström, A. & Liukko, U-M. (eds.) (2019). *The 2019 Red List of Finnish species.* Ministry of Environment and Finnish Environmental Institute, Helsinki.

Infantes, E. (2021). *Sand capping to promote eelgrass restoration*. Retrieved from: https://www.eduardoinfantes.com/sand-capping-eelgrass-restoration/

IPBES - Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (2019). *Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. E. S. Brondizio, J. Settele, S. Díaz, and H. T. Ngo (eds.). Bonn, Germany: IPBES secretariat. https://doi.org/10.5281/zenodo.3831673

IPCC – Intergovernmental Panel on Climate Change (2018). *Global Warming of 1.5°C.An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.). In Press. Retrieved from: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_High_Res.pdf

IUCN - The International Union for Conservation of Nature (2009). *No time to lose: Make full use of nature-based solutions in the post-2012 climate change regime. Position paper on the fifteenth session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP 15)*. Gland, Switzerland; IUCN.

IUCN - The International Union for Conservation of Nature (2012). *The IUCN Programme 2013–2016. Adopted by the IUCN World Conservation Congress, September 2012*. Retrieved from: https://www.iucn.org/sites/default/files/2022-05/wcc-5th-003.pdf

IUCN - The International Union for Conservation of Nature (2020). *Global Standard for Nature-Based Solutions. A User-Friendly Framework for the Verification, Design and Scaling up of NBS*. First edition. Gland, Switzerland: IUCN. Retrieved from: https://portals.iucn.org/library/sites/library/files/documents/2020-020-En.pdf

Johannesson, J. A., Tonderski, K. S., Magnus Ehde, P. & Weisner, S. E.B. (2017). Temporal phosphorus dynamics affecting retention estimates in agricultural constructed wetlands. *Ecological Engineering 103*, 436–445. http://dx.doi.org/10.1016/j.ecoleng.2015.11.050

Jönsson, A. M., Ekroos, J., Dänhardt, J., Andersson, G. K. S., Olsson, O., & Smith, H. G. (2015). Sown flower strips in southern Sweden increase abundances of wild bees and hoverflies in the wider landscape. *Biological Conservation*, 184, 51–58. https://doi.org/10.1016/j.biocon.2014.12.027

Kaye, J. P., & Quemada, M. (2017). Using cover crops to mitigate and adapt to climate change. A review. *Agronomy for Sustainable Development*, 37(1), 4.

doi:10.1007/s13593-016-0410-x

Koivula, M. & Vanha-Majamaa, I. (2020). Experimental evidence on biodiversity impacts of variable retention forestry, prescribed burning, and deadwood manipulation in Fennoscandia. *Ecological Processes 9* (11). https://doi.org/10.1186/s13717-019-0209-1

Koivula, M., Louhi, P., Miettinen, J., Nieminen, M., Piirainen, S., Punttila, P. & Siitonen, J. (2022). *Talousmetsien luonnonhoidon ekologisten vaikutusten synteesi*. Luonnonvara- ja biotalouden tutkimus 60/2022. 83 p. Retrieved from: https://jukuri.luke.fi/handle/10024/552023

Kuningas, S., Lappalainen A., Veneranta, L., & Westerborn, M. (2021). *Rannikon kalataloudellisilla kunnostuksilla tuetaan kalojen lisääntymismahdollisuuksia*. Valonia webinaari (20.04.2021). https://www.valonia.fi/wp-content/uploads/2021/06/Rannikon_kalataloudelliset_kunnostukset_Sanna_Kuningas.pdf

Kupilas, B., Burdon, F.J., Thaulow, J., Håll, J., Mutinova, P.T., Forio, M.A.E., Witing, F., Rîșnoveanu, G., Goethals, P., McKie, B.G. & Friberg, N. (2021). Forested Riparian Zones Provide Important Habitat for Fish in Urban Streams. *Water,* 13, 877. https://doi.org/10.3390/w13060877

Land, M., Granéli, W., Grimvall, A., Hoffmann, C. C., Mitsch, W. J., Tonderski, K. S., & Verhoeven, J. T. A. (2016). How effective are created or restored freshwater wetlands for nitrogen and phosphorus removal? A systematic review. *Environmental Evidence*, 5(1), 9. doi:10.1186/s13750-016-0060-0

Landgræðsluáætlun 2021-2030. (2021). Iceland. Retrieved from: https://land.is/wp-content/uploads/2021/09/20210831-Landgraedsluaaetlun.pdf

Lindberg, H., Punttila, P. & Vanha-Majamaa, I. (2020). The challenge of combining variable retention and prescribed burning in Finland. *Ecological Processes 9* (4). https://doi.org/10.1186/s13717-019-0207-3

Liquete, C., Udias, A., Conte, G., Grizzetti, B., & Masi, F. (2016). Integrated valuation of a nature-based solution for water pollution control. Highlighting hidden benefits. *Ecosystem Services, 22*, 392–401. https://doi.org/10.1016/j.ecoser.2016.09.011

Maes, J., Liquete, C., Teller, A., Erhard, M., Paracchini, M.L., Barredo, J.I., Grizzetti, B. … Meiner, A. (2016). An indicator framework for assessing ecosystem services in support of the EU Biodiversity Strategy to 2020. *Ecosystem services, 17,* 14–23. https://doi.org/10.1016/j.ecoser.2015.10.023

Magnussen, K., Wifstad, K., Seeberg, A., Stålhammar, K., Bakken, S., Banach, A., … Sandsbråten, K. (2017). *Naturbaserte løsninger for klimatilpasning*. M-830. Norway: Miljødirektoratet. Retrieved from: https://www.miljodirektoratet.no/publikasjoner/2017/oktober-2017/naturbaserte-losninger-for-klimatilpasning/

Martinez Avila, C., Alkan Olsson, J. & Hanson, I.H. (2021). Stakeholder participation in the regeneration of Ekostaden Augustenborg, in: Månsson, M., Persson, B. (Eds.), *The Eco-city Augustenborg – experiences and lessons learned.* Arkus.

McLennan, M. (2021). *The Global Risks Report 2021 16th Edition*. Cologny, Switzerland: World Economic Forum. Retrieved from: https://www.weforum.org/reports/the-global-risks-report-2021/

Ministry of Climate and Environment & Ministry of Local Government and Modernisation (2018). *Statlige planretningslinjer for klima- og energiplanlegging og klimatilpasning*. Norway: Klima- og miljødepartmentet og Kommunal- og distriktsdepartmentet. Retrieved from: https://www.regjeringen.no/no/dokumenter/statlige-planretningslinjer-for-klima--og-energiplanlegging-og-klimatilpasning/id2612821/

Ministry of Climate and Environment (2021). Meld. St. 29 (2020–2021) *Heilskapleg nasjonal plan for bevaring av viktige område for marin natur*. Norway: Klima- og miljødepartmentet. Retrieved from: https://www.regjeringen.no/no/dokumenter/meld.-st.-29-20202021/id2843433/

Myrabø, S. & Roseth, R. (1998). LOD - Aktuelle problemstillinger og naturbaserte løsninger. *VANN, 4*. Retrieved from: https://vannforeningen.no/wp-content/uploads/2015/06/1998_30841.pdf

Naturstyrelsen (2013). *Blue Reef - restoration of stone reefs in Kattegat*. Denmark: Naturstyrelsen. Retrieved from: https://naturstyrelsen.dk/media/nst/Attachments/TechnicalAn4LaymansReport.pdf

Naturvårdsverket (2021). *Naturbaserade lösningar – ett verktyg för klimatanpassning och andra samhällsutmaningar. Sweden*: Naturvårdsverket, Rapport 7016, Retrieved from: naturvardsverket.se/om-oss/publikationer/7000/naturbaserade-losningar/

Nelson, D. R., Bledsoe, B. P., Ferreira, S., & Nibbelink, N. P. (2020). Challenges to realizing the potential of nature-based solutions. *Current Opinion in Environmental Sustainability*, 45, 49–55. https://doi.org/10.1016/j.cosust.2020.09.001

Nesshöver, C., Assmuth, T., Irvine, K.N., Rusch, G.M., Waylen, K.A., Delbaere, B., Haase, D., Jones-Walters, L., Keune, H., Kovacs, E. & Krauze, K. (2017). The science, policy and practice of nature-based solutions: An interdisciplinary perspective. *Science of the total environment, 579*, 1215–1227. https://doi.org/10.1016/j.scitotenv.2016.11.106

Norwegian Agriculture Agency (2020). *Regionalt miljøtilskudd i jordbruket (RMP) – kommentarer til regelverk (Rundskrivnummer 2021/13)*. Norway: Landbruksdirektoratet. Retrieved from: https://www.landbruksdirektoratet.no/nb/jordbruk/ordninger-for-jordbruk/regionalt-miljotilskudd-rmb/regionalt-miljotilskudd-rmp--kommentarer-til-regelverk

Norwegian Biodiversity Information Centre (2021). Norwegian Red List for Species.

Retrieved from: https://www.biodiversity.no/Pages/135380/Norwegian_Red_List_for_Species

Norwegian Environment Agency (2018). *Naturbaserte løsninger for klimautfordringer i nasjonal forvaltning*. Norway: Miljødirektoratet. Retrieved from: https://www.miljodirektoratet.no/publikasjoner/2018/august-2018/naturbaserte-losninger-for-klimautfordringer-i-nasjonal-forvaltning/

Norwegian Environment Agency (2019). *Hvordan ta hensyn til klimaendringer i plan?* Norway: Miljødirektoratet. Retrieved from: https://www.miljodirektoratet.no/ansvarsomrader/klima/for-myndigheter/klimatilpasning/veiledning-til-statlige-planretningslinjer-for-klimatilpasning/

Norwegian Environment Agency (2021a). *Klimatilpasning i arealplan*. Norway: Miljødirektoratet. Retrieved from: https://www.miljodirektoratet.no/ansvarsomrader/overvaking-arealplanlegging/arealplanlegging/miljohensyn-i-arealplanlegging/klima/naturbaserte-losninger-i-klimatilpasning-og-arealplanlegging/

Norwegian Environment Agency (2021b). *Konsekvensutredninger for klima og miljø, Veileder, M-1941*. Norway: Miljødirektoratet. Retrieved from: https://www.miljodirektoratet.no/ansvarsomrader/overvaking-arealplanlegging/arealplanlegging/konsekvensutredninger/

Norwegian Environment Agency (2021c). *16 klimatilpasning-prosjekter får støtte.* Norway: Miljødirektoratet. Retrieved from: https://www.miljodirektoratet.no/aktuelt/nyheter/2021/april-2021/16-klimatilpasning-prosjekter-far-stotte/

Norwegian Environment Agency (2022). *Hvordan håndtere overvann: Oversikt over regelverk og rammebetingelser for kommunens håndtering av overvann*. Norway: Miljødirektoratet. Retrieved from: https://www.miljodirektoratet.no/ansvarsomrader/vann-hav-og-kyst/for-myndigheter/overvannshandtering/

Norwegian Public Road Administration (2005). *N200 Vegbygging – Håndbok 018.* Norway: Statens Vegvesen. Retrieved from: https://vegvesen.brage.unit.no/vegvesen-xmlui/handle/11250/2583318

Norwegian Public Road Administration (2006). *Vannbeskyttelse i vegplanlegging og vegbygging: veileder, Håndbok 261*. Norway: Statens vegvesen. Retrieved from: http://hdl.handle.net/11250/19467

Norwegian Public Road Administration (2011). *N200 Vegbygging – Håndbok 018. Norway: Statens vegvesen*. Retrieved from: https://vegvesen.brage.unit.no/vegvesen-xmlui/handle/11250/195816

Norwegian Public Road Administration (2014a). *Vannbeskyttelse i vegplanlegging og vegbygging: Statens Vegvesens rapporter, Nr. 295*. Norway: Statens vegvesen. Retrieved from: https://www.vegvesen.no/globalassets/fag/fokusomrader/miljo-og-omgivelser/295-rapport-redg27-10-15.pdf

Norwegian Public Road Administration (2014b). *N200 Vegbygging: Normal Håndbok N200 2014*. Retrieved from Statens Vegvesen: https://www.vegvesen.no/globalassets/fag/handboker/hb-n200-september-2014.pdf

Norwegian Public Road Administration. (2018). *N200 Vegbygging – Vegnormal N200: 2018*. Retrieved from Statens Vegvesen: https://www.vegvesen.no/globalassets/fag/handboker/hb-n200-vegbygging-juli-2018.pdf

Norwegian Public Road Administration. (2021). *N200 Vegbygging – Vegnormal N200*. Retrieved from Statens Vegvesen: https://store.vegnorm.vegvesen.no/svv-proj-1464925

Norwegian Water Resources and Energy Directorate (2022). *Rettleiar for handtering av overvatn i arealplanar: Korleis ta omsyn til vassmengder?, Norway: Noregs vassdrags- og energidirektorat*. Retrieved from: https://publikasjoner.nve.no/veileder/2022/veileder2022_04.pdf

Odense municipality. (2022). *Klimahandleplan*. Retrieved from: https://www.odense.dk/byens-udvikling/klima/klimaneutral-2030/klimahandleplan-2022

Oppla (2022). *Case studies: Blue Reef Project: Rebuilding of Marine Cavernous Boulder Reefs in Kattegat*. Retrieved from: https://oppla.eu/casestudy/26817

Oslo municipality (n.d.). Oslotrær. Retrieved from: https://www.oslo.kommune.no/slik-bygger-vi-oslo/oslotrar/#gref

Overland, J. E., Wang, M. & Box, J. E. (2019). An integrated index of recent pan-Arctic climate change. *Environmental Research Letters*, 14(3), 035006. https://doi.org/10.1088/1748-9326/aaf665

Palmé, A. (n.d.a). NordGen. *Conservation Tools*. Retrieved from: https://www.nordgen.org/en/our-projects/cwr-conservation-planning/cwr-conservation-tools/

Palmé, A. (n.d.b) *NordGen. Crop Wild Relatives*. Retrieved from: https://www.nordgen.org/en/projekts/crop-wild-relatives/

Palmé, A., Fitzgerald, H.; Weibull, J., Bjureke, K., Eisto, K.; Endresen, D., Hagenblad, J., Hyvärinen, M., Kiviharju, E. & Lund, B. (2019). *Nordic Crop Wild Relative conservation: A report from two collaborative projects 2015–2019*, Nordic Council of Ministers. Retrieved from: http://norden.diva-portal.org/smash/record.jsf?pid=diva2%3A1335894&dswid=5026

Pedersen, M. L., Friberg, N., Skriver, J., Baattrup-Pedersen, A., & Larsen, S. E. (2007). Restoration of Skjern River and its valley—Short-term effects on river habitats, macrophytes and macroinvertebrates. *Ecological Engineering, 30(2)*, 145–156. Doi: 10.1016/j.ecoleng.2006.08.009

Pettorelli, N., Graham, N. A. J., Seddon, N., Maria da Cunha Bustamante, M., Lowton, M. J., Sutherland, W. J., Koldewey, H. J.,
Prentice, H. C., & Barlow, J. (2021). Time to integrate global climate change and biodiversity science-policy agendas. *Journal of Applied Ecology*, 58, 2384– 2393. https://doi.org/10.1111/1365-2664.13985

Peurasuo, P., Saarikko, J., Tegel, S., Terho, M., Ylikotila, T. (2014). *Urban Tree Policy.* City of Helsinki – Public Works department. Helsingin kaupungin rakennusviraston julkaisut 2014:8. Retrieved from: https://vihreatsylit.fi/hk/pdf/kaupunkipuulinjaus_en.pdf

Prudencio, L., & Null, S. E. (2018). Stormwater management and ecosystem services: a review. *Environmental Research Letters, 13(3),* 033002. https://doi.org/10.1088/1748-9326/aaa81a

Quintana C.O., Kristensen E. & Petersen S.G.G. (2021). *Kystsikring og tilpasning til stigende havvandstand: økologiske konsekvenser og innovative løsninge*r. Notat, maj 2021, Syddansk Universitet, Odense. Retrieved from: https://realdania.dk/publikationer/faglige-publikationer/kystsikring-og-tilpasning-til-stigende-havvandstand

Rasmussen, J. J., Baattrup-Pedersen, A., Wiberg-Larsen, P., McKnight, U. S., & Kronvang, B. (2011). Buffer strip width and agricultural pesticide contamination in Danish lowland streams: Implications for stream and riparian management. *Ecological Engineering, 37(12)*, 1990–1997. https://doi.org/10.1016/j.ecoleng.2011.08.016

Raspati, G. S., Bruaset, S., Sivertsen, E., Møller-Pedersen, P. & Røstum, J. (2019). *Documentation tool of nature-based solutions – a guideline.* Klima 2050 Report 18, Norway: SINTEF akademisk forlag. Retrieved from: http://hdl.handle.net/11250/2628840

Raymond, C., Breil, M., Nita, M., Kabisch, N., de Bel, M., Enzi, V., Frantzeskaki, N., Geneletti, G., ... Berry, P. (2017). *An impact evaluation framework to support planning and evaluation of nature-based solutions projects*. Report prepared by the EKLIPSE Expert Working Group on Nature-based Solutions to Promote Climate Resilience in Urban Areas. Centre for Ecology and Hydrology. Retrieved from: https://www.eklipse-mechanism.eu/apps/Eklipse_data/website/EKLIPSE_Report1-NBS_FINAL_Complete-08022017_LowRes_4Web.pdf

Reid, A. J., Carlson, A. K., Creed, I. F., Eliason, E. J., Gell, P. A., Johnson, P. T., ... Cooke, S. J. (2019). Emerging threats and persistent conservation challenges for freshwater biodiversity. *Biological Reviews, 94(3)*, 849–873. https://doi.org/10.1111/brv.12480

Ridley, D. (2012). *The Literature Review: a step-by-step guide for students.* SAGE.

Routa, J. & Huuskonen, S. (eds.) (2022). *Jatkuvapeitteinen metsänkasvatus: synteesiraportti*. Luonnonvara- ja biotalouden tutkimus 40/2022, 75–83. Retrieved from: http://urn.fi/URN:ISBN:978-952-380-427-2

Salmond, J. A., Tadaki, M., Vardoulakis, S., Arbuthnott, K., Coutts, A., Demuzere, M., ... Wheeler, B. W. (2016). Health and climate related ecosystem services provided by street trees in the urban environment. *Environmental Health, 15(1)*, 95–111. https://doi.org/10.1186/s12940-016-0103-6

Sarvilinna, A., Lehtoranta, V. & Hjerppe, T. (2017). Are Urban Stream Restoration Plans Worth Implementing?. *Environmental Management 59*, 10–20. https://doi.org/10.1007/s00267-016-0778-z

Satori, D., Tovar, C., Faruk, A., Hammond Hunt, E., Muller, G., Cockel, C., Kühn, N., Leitch, I.J. ... Pironon, S. (2021). Prioritising crop wild relatives to enhance agricultural resilience in sub-Saharan Africa under climate change. *Plants, People, Planet 2022(4)*, 269–282. https://doi.org/10.1002/ppp3.10247

Seddon, N. (2022). Harnessing the potential of nature-based solutions for mitigating and adapting to climate change. *Science, 376(6600)*, 1410–1416. https://doi.org/10.1126/science.abn9668

Seddon, N., Chausson, A., Berry, P., Girardin, C. A., Smith, A., & Turner, B. (2020). Understanding the value and limits of nature-based solutions to climate change and other global challenges. *Philosophical Transactions of the Royal Society B*, 375(1794), 20190120. https://doi.org/10.1098/rstb.2019.0120

Siitonen, J., Punttila, P., Korhonen, K.T., Heikkinen, J., Laitinen, J., Partanen, J., Pasanen, H. & Saaristo, L. (2020). *Talousmetsien luonnonhoidon kehitys vuosina 1995–2018 luonnonhoidon laadun arvioinnin sekä valtakunnan metsien inventoinnin tulosten perusteella.* Luonnonvara- ja biotalouden tutkimus 69/2020. Retrieved from: http://urn.fi/URN:ISBN:978-952-380-056-4

Sivertsen, E., Raspati, G. S., Barrio, M., Bruaset, S. & Azrague, K. (2021). *Forurenset overvann. En litteraturstudie.* Klima 2050 Report 28. Norway: SINTEF akademisk forlag. Retrieved from: https://hdl.handle.net/11250/2832992

SLA (2019). *Biodiversitet i fremtidens byer og samfund: Forslag til natur- og biodiversitetspakke 2019.* København, Denmark: SLA. Retrieved from: https://mim.dk/media/218051/forslag_til_biodiversitetspakken_final.pdf

SLU Artdatabanken (2020). *The Swedish Red List 2020*. Retrieved from: https://www.gbif.org/dataset/23c0a6c4-f1f4-4577-ac5c-98787c1a2d0c

Sowińska-Świerkosz, B. & García, J. (2022). What are Nature-based solutions (NBS)? Setting core ideas for concept clarification. *Nature-Based Solutions, 2*, 100009. https://doi.org/10.1016/j.nbsj.2022.100009

State of Green (2015). *100,000 New Trees for Copenhagen.* Retrieved from: https://stateofgreen.com/en/news/100000-new-trees-for-copenhagen/

State of Green (2021). *Nature Based Solutions: Using rainwater as a resource to create resilient and liveable cities (Version 2.1)*. Retrieved from: https://stateofgreen.com/en/wp-content/uploads/2021/03/SoG_WhitePaper_LAR_2020_210x297_V11_WEB.pdf

Strand, J. A. & Weisner, S. E. B. (2013). Effects of wetland construction on nitrogen transport and species richness in the agricultural landscape—Experiences from Sweden; *Ecological Engineering 56* 14–25. https://doi.org/10.1016/j.ecoleng.2012.12.087

Swann, S., L. Blandford, S. Cheng, J. Cook, A. Miller & R. Barr. (2021). *Public International Funding of Nature-based Solutions for Adaptation: A Landscape Assessment.* Working Paper. Washington, DC: World Resources Institute. Retrieved from: https://doi.org/10.46830/wriwp.20.00065

Swedish Portal for Climate Change Adaptation (2018). *Trees in urban environments.* Retrieved from: https://www.klimatanpassning.se/en/cases/trees-in-an-urban-environment-1.114276

Syversen, N. (2005). Effect and design of buffer zones in the Nordic climate: The influence of width, amount of surface runoff, seasonal variation and vegetation type on retention efficiency for nutrient and particle runoff. *Ecological Engineering 24*, 483–490. https://doi.org/10.1016/j.ecoleng.2005.01.016

Tarevoktere (2019). Kelp Forest Restoration. Retrieved from: https://www.tarevoktere.org/no/hjem/

The Soil Conservation Service of Iceland (2021a). *Endurheimt votlendis, Leiðbeiningar fyrir framkvæmdaaðila*. Retrieved from https://land.is/wp-content/uploads/2021/08/Endurheimt-votlendis.-Leidbeiningar-fyrir-framkvaemdaadila.pdf

The Soil Conservation Service of Iceland (2021b). N*ýtt leiðbeiningarit um endurheimt votlendis komið út*. Retrieved from: https://land.is/nytt-leidbeiningarrit-um-endurheimt-votlendis/

The Soil Conservation Service of Iceland (2021c). *Vel heppnuð endurheimt votlendis á Snæfellsnesi vekur athygli á vettvangi Sameinuðu þjóðanna.* Retrieved from: https://land.is/vel-heppnud-endurheimt-votlendis-a-snaefellsnesi-vekur-athygli-a-vettvangi-sameinudu-thjodanna/

The Soil Conservation Service of Iceland (2021d). *Votlendi.* Retrieved from: https://land.is/heim/malaflokkar/endurheimt-votlendis/

The Soil Conservation Service of Iceland. (n.d.) *Bændur græða landið.* Retrieved from: https://land.is/heim/malaflokkar/baendur-graeda-landid/

Thiere, G., Milenkovski, S., Lindgren, P.-E., Sahlén, G., Berglund, O., & Weisner, S. E. B. (2009). Wetland creation in agricultural landscapes: Biodiversity benefits on local and regional scales. *Biological Conservation, 142(5)*, 964–973. https://doi.org/10.1016/

j.biocon.2009.01.006

Thomas, D. N., Arévalo-Martínez, D. L., Crocket, K. C., Große, F., Grosse, J., Schulz, K., … Tessin, A. (2022). A changing Arctic Ocean. *Ambio, 51(2),* 293–297. https://doi.org/10.1007/s13280-021-01677-w

Thorbjörnsson, H. & Göransson, M. (n.d.) *Pilot Project: Biodiversity in Urban and Coastal Areas in Iceland*. Retrieved from: https://networknature.eu/pilot-project-biodiversity-urban-and-coastal-areas-iceland

Timonen, J., Gustafsson, L., Kotiaho, J.S. & Mönkkönen, M. (2011). Hotspots in cold climate: conservation value of woodland key habitats in boreal forests. *Biological Conservation 144*, 2061–2067. https://doi.org/10.1016/j.biocon.2011.02.016

Toxopeus, H., & Polzin, F. (2021). Reviewing financing barriers and strategies for urban nature-based solutions. *Journal of Environmental Management, 289,* 112371. https://doi.org/10.1016/j.jenvman.2021.112371

UNEP - United Nations Environment Programme (2022). *Nature-based solutions for supporting sustainable development: Resolution adopted by the United Nations Environment Assembly on 2 March 2022*. Kenya: Nairobi. Retrieved from: https://wedocs.unep.org/20.500.11822/39752

Uusi-Kämppä, J., Braskerud, B., Jansson, H., Syversen, N & Uusitalo, R. J. (2000). Buffer Zones and Constructed Wetlands as Filters for Agricultural Phosphorus, *Journal of Environmental Quality, 29*, 151–158. https://doi.org/10.2134/jeq2000.00472425002900010019x

Vejle municipality. (2020). Stormflodsstrategi: *Stormflodsbeskyttelse der gror med byen*. Retrieved from: https://www.vejle.dk/media/35150/201202-stormflodsstrategi.pdf

Venter, Z. S., Barton, D. N., Gundersen, V., Figari, H. & Nowell, M. (2020a). Urban nature in a time of crisis: Recreational use of green space increases during the COVID-19 outbreak in Oslo, Norway. *Environmental research letters, 15(10)*, 104075. https://doi.org/10.1088/1748-9326/abb396

Venter, Z. S., Barton, D. N., Gundersen, V., Figari, H. & Nowell, M. S. (2021). Back to nature: Norwegians sustain increased recreational use of urban green space months after the COVID-19 outbreak. *Landscape and Urban Planning, 214*, 104175. https://doi.org/10.1016/j.landurbplan.2021.104175

Venter, Z. S., Krog, N. H., & Barton, D. N. (2020b). Linking green infrastructure to urban heat and human health risk mitigation in Oslo, Norway. *Science of the total environment, 709,* 136193. https://doi.org/10.1016/j.scitotenv.2019.136193

Viti, M., Löwe, R., Sørup, H. J., Rasmussen, M., Arnbjerg-Nielsen, K., & McKnight, U. S. (2022). Knowledge gaps and future research needs for assessing the non-market benefits of Nature-Based Solutions and Nature-Based Solution-like strategies.

Science of the Total Environment, 841, 156636. https://doi.org/10.1016/j.scitotenv.2022.156636

Wai, K. T. (2022). *Optimizing Phytoremediation to Enhance Treatment Efficiency of Suspended Raingardens.* Doctoral dissertation, Department of Civil and Environmental Engineering, The University of Auckland. Retrieved from: https://researchspace.auckland.ac.nz/bitstream/handle/2292/58597/Wai-2022-thesis.pdf?sequence=2

Wamsler, C., Alkan-Olsson, J., Bjorn, H., Falck, H., Hanson, H., Oskarsson, T., Simonsson, E., Zelmerlow, F., (2019). Beyond participation: when citizen engagement leads to undesirable outcomes for nature-based solutions and climate change adaptation. *Climatic Change 158*, 235–254 (2020). https://doi.org/10.1007/s10584-019-02557-9

World Bank (2008). *Biodiversity, Climate Change and adaptation: Nature-Based solutions from the World Bank Portfolio.* Washington D.C.: World Bank. Retrieved from: http://hdl.handle.net/10986/6216

WWF (2020). *Flere og bedre naturoplevelser til danskerne: WWF Verdensnaturfondens naturpolitiske forslag til natur- og biodiversitetspakken.* Retrieved from: https://mim.dk/media/218115/wwf_verdensnaturfondens_forslag_til_natur-_og_biodiversitetspakken.pdf

Yue, C., Li, L. Y., & Johnston, C. (2018). Exploratory study on modification of sludge-based activated carbon for nutrient removal from stormwater runoff. *Journal of environmental management, 226*, 37–45. https://doi.org/10.1016/j.jenvman.2018.07.089

Zak, D., Stutter, M., Jensen, H. S., Egemose, S., Carstensen, M. V., Audet, J., Strand, J. A., Feuerbach, P. … Kronvang, B. (2019). An assessment of the multifunctionality of integrated buffer zones in Northwestern Europe. *Journal of Environmental Quality, 48(2)*, 362–375. https://doi.org/10.2134/jeq2018.05.0216

Zölch, T., Henze, L., Keilholz, P. & Pauleit, S. (2017). Regulating urban surface runoff through nature-based solutions–an assessment at the micro-scale. *Environmental research, 157*, 135–144. https://doi.org/10.1016/j.envres.2017.05.023

Aanderaa, T., Bruaset, S., Jensen, L. C., Paus, K.H., Rønnevik, J. S., & Sivertsen. E. (2021). *Løsningen er naturbasert: en kartlegging av forvaltningens behov for brukerstøtte innen naturbaserte løsninger for klimatilpasning*. Asplan Viak. Retrieved from: https://www.miljodirektoratet.no/publikasjoner/2021/januar-2021/losningen-er-naturbasert/

9 Appendices

9.1 Grey literature search (including policy)

9.1.1 Denmark

Method

The grey literature research in Denmark was conducted two times first in January 2022 and repeated again in July 2022. In both cases a two-step approach was applied using solely the Danish search term "naturbaserede løsninger" or just "naturbaserede" as the majority of hits only referred to other type of solutions rather than nature-based solutions. In the first step webpages from public authorities and main academic institutions were visited working with ecosystems considered in this project (see detailed description of methodology in chapter 3.2). These targeted institutions have been i) two centres which are related to the Aarhus University: the DCA – Danish Center For Food And Agriculture, DCE – Danish Center For Environment And Energy, ii) three ministries: The Ministry of Environment, The Ministry of Food, Agriculture and Fisheries of Denmark, The Ministry of Transport, iii) three further Danish Universities: the Universities of Copenhagen, Aalborg, Southern Denmark and the Danish Technical University and iv) finally the "Danske Regioner" (https://www.regioner.dk), the five largest local governments based on inhabitants (Copenhagen, Aarhus, Aalborg, Odense and Vejle) and 15 randomly-selected governments were considered. In the second step a Google search was conducted focusing on Danish webpages. From the 2240 hits only the first 50 were analysed in detail. In most cases, the hits neither for the first step (academia, authorities, municipalities) nor in the broader second step of the Googles search were relevant. The term was often used without any context of planned or implemented projects but in a very unspecific manner as loose statement, in context of oral presentations or meeting minutes. From the total of 7602 hits only 28 documents have been found relevant to be listed in the "grey literature matrix" for further analysis.

Governmental requirements for adopting NBS

The government of Denmark has compared to some other Nordic countries so far not adopted the NBS concept in their legislation and policy strategies. The term as such is used in some documents of the Ministry of Environment but it is currently more exclusively used to give an outlook on future implementation of restoration measures like rewetting of organic lowlands but not consolidated in their governmental framework or formulating any specific requirements to be addressed by public or private actors. However, the Danish parliament has adopted a subsidy scheme to incentivise landowners to take 100.000 ha drained organic soils out of production and rewet them to decrease the GHG emission from agriculture (Klimarådet, 2020).

Quite a few municipalities in Denmark are on the way to create more sustainable urban communities. Via nature-based solutions, urban areas and urban spaces have been prepared for climate change and are more valuable for the city and its citizens. Specifically, they recognized at the one hand the value of nature-based climate adaptations to mitigate against extreme rain, and at the other hand they are aiming for greener cities to make them more attractive to citizens. For example, Vejle (2020)[19] as a coastal city developed a comprehensive storm surge strategy to protect the citizens and at the same time raising the quality of life. Odense municipality (2022)[20] developed a detailed climate action plan to become greener and climate neutral in 2030 already which includes NBS measure in forests, lowland areas and coastal zones but is also involved as partner in a targeted EU research proposal.

Support provided to facilitate NBS

Public authorities
In face of rising sea water levels and higher risks of damages by storm surges the Danish regions (2022) developed seven recommendations for a national climate adaption plan including the implementation of NBS like restoration of wetlands. Moreover, an EU´s Horizon 2020 project[21] will restore a coastal area promoting synergies between climate adaptation, efforts for nature, outdoor life and nitrogen-reducing measures.

Knowledge providers
Currently there is only a handful of research projects addressing explicitly the implementation and monitoring of the efficiency of NBS in Denmark.

For example, a project from Southern Denmark University (SDU) post-evaluated different case studies on NBS in coastal areas to draw recommendations and a framework how NBS can be implemented to recover the ability of coastal areas to filter nutrients, capture fine particles and maintain a rich biodiversity of flora and fauna (Quintana et al., 2021). Authors of this report would like to inspire actors to use innovative solutions that can simultaneously tackle climate change and restore a more harmonious seascape in connection with future developments of urban areas and suburban areas. Finally, they emphasized the urgent need for more competencies which involve environmental and architectural aspects as well as administrations and societal sectors to support the planning and implementation of NBS in coastal protection.

Another recent example of a research project is the post-evaluation of eight NBS cases in the Nordic countries of Denmark, Finland, Iceland, Norway and Sweden which was done by The Danish IPBES Office together with Copenhagen University (Dinesen et al., 2021). The final scientific report concludes with 10 policy options on how to conserve and restore peatlands and forests to combat the two global environmental crises, the loss of biodiversity and climate change. Overall, research

19. Vejle (2020), Stormflodsstrategi. https://www.vejle.dk/media/35150/201202-stormflodsstrategi.pdf
20. Odense municipality (2022), Klimahandleplan. https://www.odense.dk/byens-udvikling/klima/klimaneutral-2030/klimahandleplan-2022
21. Salt meadow and several breeding sites help with climate protection of Seden Strandby (Odense commune, 2020). https://cordis.europa.eu/project/id/101037097

on greenhouse gas emissions is perhaps one of the most rapid developing research fields from the local to the global level. Nevertheless, there is still a lack of cases in Denmark with field studies running a monitoring of greenhouse gas fluxes and/or biodiversity, but few started recently (e.g., ReWet; rojects.au.dk/rewet).

Based on research experiences during the last decades rather robust advice is given from researchers at Aarhus University on the great potential of NBS to clean water (Ministry of children and education, 2021). This includes a range of NBS being either more technical and small-scale such as different types of constructed wetlands or such without further maintenance like large-scale wetland restoration.

Copenhagen University has defined a number of research avenues in the context of nature-based climate solutions to foster the so-called "Green Transition" in Denmark in different sectors of industry, agriculture and environment.[22]

Finally, in addition to research institutions there are also private/interest organisations like SLA, "Green cities Denmark" and "State of Green" which are active to strengthen the Nature and Biodiversity Package of Denmark by combining knowledge and competences from different stakeholders and actors to facilitate a nature-based holistic approach as well as to complement the work with real solutions for integrating nature and biodiversity in society.

Ongoing research activities

Research activities are focusing on the effects of NBS on different environmental and societal benefits. There is for example demand for research and funding on the establishment of stone reefs in the coastal zone to protect coastline and increase the biodiversity at the same time. On the other hand it is suggested to remove artificial flood barriers at Danish coasts and using nature-based climate protection solutions instead. In the scope of an EU funded project "REGREEN", Aarhus University in collaboration with other research institutions, city authorities, consultancies and city networks are aiming to improve the evidence and tools for supporting co-creation of NBS in urban settings, implementation of decision support systems for planning and governance, and development of business models for realising spatially relevant NBS, that provide multiple ecosystem services and wellbeing.[23] Likewise, in the urban context there is ongoing research on sustainable solutions for rainwater mitigation, e.g., Danish Technical University is developing a digital tool in order to design nature-based rainwater solutions.[24]

22. Københavns Universitet, Institut for Geovidenskab og Naturforvaltning. https://ign.ku.dk/forskning/
23. See for example Greenopolis. https://www.intugreen.dk/greenopolis/da/om-greenopolis/
24. Center for Water Activities at DTU, Inklusion af regnbede i SCALGO Live ved kobling til DTUs LAR-potentialeberegner. https://water.dtu.dk/VIS/Projektbeskrivelser/Scalgo

Table 7. Support material provided to facilitate NBS planning, implementation and management by academic institutions, consultancies and interest organizations in Denmark.

Academic institutions, consultancies and interest organisations	Environment and climate	Primary industries	Land-use planning	Infrastructure
Guidelines and tools	Ecological restoration of coastal areas by including environmental, architectural and cultural aspects as well as the participation of administrations and societal sectors with the aim of preparing optimal NBS.[1] WWF's nature policy proposal for the nature and biodiversity package incl. initiatives for a greener Denmark also to improve the opportunity for private individuals to strengthen biodiversity[2]			Nature-based solutions for rainwater management in Danish cities[7] Shaping cities by nature-based solution for climate adaption and green urban development[8] Teaching material about sustainable urban development, climate adaption and NBS[9] A numeric tool for planning the construction of urban rain beds[10]
In-depth knowledge targeting practitioners and public administration	Conserve and restoration of peatlands and forests to combat two global environmental crises, the loss of biodiversity and climate change[3] Scientific literature review to analyse key options for nature-based solutions and their multiple benefits, as well as their potential trade-offs and limitations for relevant sectors in Europe (water, forests and forestry, agriculture, urban and coastal areas)[4]			
General information for the public	Establishment of artificial reefs to protect the coast and support processes improving water quality and biodiversity[5]		Restoration of wetlands and implementation of nature-based technologies to obtain clean fresh water[6]	NBS to protect coastal cities against storm surges[11] Development of sustainable green cities[12]

References:
[1] Coastal protection and adaptation to rising sea levels: ecological consequences and innovative solutions (Quintana et al., 2021)
[2] More and better nature experiences for the Danes WWF's proposals for efforts and content (WWF, 2020)
[3] Synergi in conservation of biodiversity and climate change mitigation – Nordic peatlands and forests (Dinesen et al., 2021).
[4] Nature-based solutions in Europe: Policy, knowledge and practice for climate change adaptation and disaster risk reduction (European Environment Agency, 2021)
[5] Rock reefs in the coastal zone (Foreningen Hunderevet, 2019)
[6] Recreated wetlands and clean fresh water (Ministry of children and education, 2021).
[7] The climate battle, 12 solutions for rainwater management (Green Cities Denmark, 2021)
[8] Nature based solutions - Using rainwater as a resource to create resilient and liveable cities (State of Green, 2021)
9 Greenopolis (INTUGREEN, 2019)
[10] Inclusion of rainbeds in SCALGO Live by linking to DTU's LAR potential calculator (DTU, 2022)
[11] Architectural researchers: Drop the high-water walls and use nature-based climate protection instead (Klimamonitor, 2022)
[12] Climate adaptation – from thought to action (Aktuelt Naturvidenskab, 2020)

9.1.2 Finland

Method

The grey literature search for Finland was conducted in January-March 2022 and included all steps including snowballing. The national government (including all ministries) and relevant national governmental bodies were targeted. The five largest county (region, maakunta) authorities and 15 randomly-selected municipalities (kunta) were targeted. As to the academic literature, relevant institutes (Natural Resources Institute Finland (Luke), Finnish Environment Institute (Syke), European Forest Institute (EFI), Metsähallitus Luontopalvelut, Ministries of Agriculture & Forestry and Environment) and universities providing environmental education and research (Helsinki, Turku, Jyväskylä, Tampere, Eastern Finland, Lapland, Aalto) were targeted either directly through their own databases[25] or through Theseus database for theses made in universities of applied sciences[26] and Finna database for national libraries, including universities.[27] We also applied a Google search for other sources, including commercial and non-commercial organizations (e.g., World Wildlife Fund, ProAgria). All publications found during this exercise which included the term nature-based solutions, were added to the matrix. The searches concerned all publications until present (2022).

Some sources produced multiple hits for "nature-based solutions" (e.g., 62 in the city of Helsinki web page alone; 19 Jan 2022). However, after pruning duplicates or non-projects we ended up having only 26 unique documents and websites to be added to the Finnish data matrix. All detected materials were published during the last seven years. The earliest was a description of the project "Nature-based solutions for societal challenges" by the Finnish Environment Institute (Syke) from 2016.

Governmental requirements for adopting NBS

Finland has not at any administrative level (national, regional and municipal) adopted the NBS concept or any requirements for NBS adoption. However, assuming NBS is understood widely as containing restoration, rehabilitation and close-to-nature environmental management, Finnish legislation (without mentioning NBS specifically) forces the landowner or land manager to carry out certain NBS actions. These mostly relate to protection of water quality, including ground water, lakes and streams, and conservation of habitat types of known importance for biodiversity (key biotopes). Examples are the Finnish Nature Conservation Act, Forest Act, Water Act, The Sustainable Forest Management Funding Act (KEMERA), The Forest Biodiversity Programme of Southern Finnish Forests (METSO), and the HELMI environmental programme.

25. See for example University of Helsinki, publications. https://researchportal.helsinki.fi/fi/publications/
26. Open Repository Theseus - the theses and publications of the Universities of Applied Sciences on the Internet. https://www.theseus.fi/
27. Finna.fi, a search service for finding fascinating material from archives, libraries, museums and other organisations. https://www.finna.fi/?lng=en-gb

Support provided to facilitate NBS

Out of the 17 identified supporting grey-literature materials, eight were press releases or blogs describing the importance of NBS. A total of seven of these came from the Ministry of Agriculture and Forestry and from the Ministry of Environment, whereas the rest were from Luke or Syke. Four of the documents described research projects, four reported on NBS results, and one was a policy paper by the Ministry of Environment with international collaborators. Furthermore, ten documents described urban or "artificial" environments, and quite a few dealt with forest, freshwater or agricultural habitats.

Table 8. Support material provided to facilitate NBS planning, implementation and management by national authorities in Finland.
Material resulting from commissions from the public authorities is sorted under the actor who commissioned the projects.

National authorities	Environment and climate	Primary industries	Land-use planning	Infrastructure
Guidelines and tools	EU preparations for UN biodiversity targets[1]			
In-depth knowledge targeting practitioners and public administration	Open-air laboratories for nature-based solutions to manage environmental risks[2] Finnish biodiversity strategy evaluation[3] Sustainable recovery boosts the necessary transformations in society[4] Suomen biodiversiteettistrategian ja toimintaohjelman 2012–2020 toteutuksen ja vaikutusten arviointi3Evaluation of national forest strategy 2025[5]	Evaluation of national forest strategy 20256	Finnish biodiversity strategy evaluation[3] Suomen biodiversiteettistrategian ja toimintaohjelman 2012–2020 toteutuksen ja vaikutusten arviointi[3] Evaluation of national forest strategy 2025[5]	
General information for the public (e.g., webpages, fact sheets)	Building a climate-resilient Europe – Commission published a new EU Strategy on Adaptation to Climate Change[9]			
	Biodiversity loss can be stopped[6] Finland has good possibilities to utilize NBS in climate change adaptation and protecting biodiversity[7] Best Finnish action for nature was "Save the bee"-campaign by YLE[8]			

References:
[1] EU Preparations for UN Biodiversity Targets (EU2019.FI – Finland's Presidency of the Council of the European Union).
[2] Open-air laboratories for nature-based solutions to manage environmental risks. OPERANDUM. (Luke)
[3] Suomen biodiversiteettistrategian ja toimintaohjelman 2012–2020 toteutuksen ja vaikutusten arviointi (Statsrådet, 2020) https://urn.fi/URN:ISBN:978-952-287-915-8
[4] Sustainable recovery boosts the necessary transformations in society (Ministry of the Environment, 2020).
[5] Kansallinen metsästrategia 2025 – päivitys. (Ministry of Agriculture and Forestry of Finland 2019).
[6] Luonnon monimuotoisuuden väheneminen voidaan pysäyttää (Syke - Finnish Environment Institute, 2020)
[7] Undersökning: I Finland finns det goda förutsättningar att utnyttja naturbaserade lösningar vid anpassningen till klimatförändringarna och vid bevarandet av den biologiska mångfalden (Statsrådets utrednings- och forskningsverksamhet, 2019).
[8] Den bästa insatsen för naturen 2019–2020 var Yles kampanj Pelasta pörriäinen (Miljøministeriet, 2021)
[9] Building a climate-resilient Europe – Commission published a new EU Strategy on Adaptation to Climate Change (Ministry of Agriculture and Forestry Finland, 2021)

9.1.3 Iceland

Method

The grey literature search for Iceland was undertaken between December 2021 and June 2022. First, the English and Icelandic terms (náttúrulegar lausnir, náttúrumiðaðar lausnir) for NBS were searched, but yielded only few results. First, national authorities' and agencies' websites were targeted, such as Umhverfisstofnun (Environment Agency of Iceland), Landvernd (Icelandic Environment Association) and the Government of Iceland with its ministries. Next, search engines were searched, starting with google scholar for academic papers, Skemman, the national academic database including all universities, and finally google. Furthermore, all regional websites (Iceland does not have regional governments as such) were targeted, as well as 15 local authorities (ten most populous and five random). With this initial search, only eight relevant results were found. Of those, four came from the government, three from academic papers and one from Reykjavik municipality.

Due to the low number of results of the direct terms for NBS in Iceland, the search was expanded by snowballing. The alternative terms used included Blágrænar ofanvatnslausnir/Blue-green surface water solutions, Ecological soil restoration, Vistheimt/Ecological restoration, Sjálfbærar ofanvatnslausnir/ Sustainable surface water solutions, Endurheimt votlendis/Wetland restoration and Blue green water drainage solutions. Those additional searches yielded nine additional results. Of those, three were academic publications (two research projects and one report), two from the Soil Conservation Service of Iceland, one from a regional authority and three from private actors. Most were reports, with one exception of a PowerPoint presentation from a consulting agency.

The results provided in chapter 4.2 are based on the material identified using the NBS term.

Governmental requirements for adopting NBS

There are currently no binding governmental requirements for adopting NBS in Iceland. However, national authorities have repeatedly stated an interest in and a willingness to push for implementation of nature-based solutions on a rather general scale. They often mention afforestation – a historic issue in a soil-poor, erosive country – as well as reclaiming wetlands to store carbon and help with flooding issues. These two main foci can be seen in the policies and statements as mentioned in the Table 9 below.

On a regional and local authority level, the only results that could be found were dealing with blue-green surface water solutions in Urriðaholt municipality and raingardens and surface water solutions in the municipality of Reykjavík. They were found using alternative search terms.

Table 9. Governmental requirements for adopting NBS from the national authorities in Iceland.

National authorities	Environment and climate	Primary industries	Land-use planning	Infra-structure
Laws and regulations				
Policies, strategies and plans	NBS as one of the future scenarios discussed with stakeholders in the Low Emission Development Strategy[1] Environmental Minister stresses the importance of nature-based solutions like afforestation, revegetation, and reclamation of wetlands, detailing the official line of strategy of the Icelandic Government on NBS[2]			
	Prime Ministerial announcement of intent to be more ambitious in environmental development and push NBS3,4			
	The Iceland Scientific Committee on Climate Change has estimated that a large proportion of greenhouse gas emissions in Iceland come from drained wetlands. Land wetlands (moorland) cover about 9000 km2 or about 20% of the green area of Iceland. It is estimated that about 50% of the area has been disturbed by drainage. Wetland types in Iceland include swamps, bays, lakes and streams, seaweeds, mud and beaches, as well as shallowly down to a depth of six meters. In the spring of 2016, the Soil Conservation Service of Iceland was assigned for wetland restoration projects in accordance with the Icelandic Government's Strategy on Climate Change. In 2019, six areas were reclaimed in cooperation with different stakeholders.5			

References:
[1] On the Path to Climate Neutrality - Iceland's Long-term Low Emission Development Strategy (Ministry for the Environment and Natural Resources, 2021)
[2] Increased efforts for climate adaptation, nature-based solutions (Government of Iceland, 2021)
[3] Iceland announces enhanced ambition at Climate Ambition Summit (Prime Minister, 2020)
[4] Prime Minister's address at the Arctic Circle October 10th, 2019 (Prime Minister, 2019)
[5] Wetland Restoration 2019 (The Soil Conservation Service of Iceland, 2021)

Support provided to facilitate NBS

Public authorities

Iceland does not have an overarching strategy to support NBS projects as the term is not yet widely used in policies. However, NBS seems to be gaining momentum in Iceland as is evident by current seminars, workshops and practitioner meetings and we expect a deepening of meaningful engagement with the concept, including facilitation support, in the near future.

Knowledge providers

There is no consolidated effort to provide guidance on NBS implementation due to the lack of use of the term and concept up until now. NBS is largely described by scientific literature and projects in Iceland, although not cohesively called NBS either, and thus the knowledge providers tend to be research institutions and those linked with environmental science, namely the Soil Conservation Service of Iceland (n.d.), the Icelandic Forest Service, the Icelandic Agricultural Advisory Centre (RML), the Icelandic Wetland Fund, Reykjavik City municipality, the University of Iceland and the Agricultural University of Iceland.

9.1.4 Norway

Method

The grey literature search for Norway was conducted from December 2021 to June 2022 and included all steps including some snowballing. The search was undertaken using the Norwegian (bokmål) and New Norwegian (nynorsk) translation of the NBS term. The national government (including all ministries) and several national governmental bodies were targeted.[28] All 11 county authorities were targeted,[29] and 20 municipalities.[30] As to academic literature, seven research institutes were targeted, as were the national academic database, CRISTin. All publications found during this exercise which included the term nature-based solutions, were added to the matrix, as were some publications using related terms.[31] The searches were not limited to 2010–2022, because it was not expected to find any publications published before 2010, considering that the NBS term is relatively new.

201 unique documents and websites were added to the Norwegian data matrix, of which 86% were deemed relevant. As expected, the publications were primarily published the last five years, but four relevant documents were published in the late 1990s and early 2000s. The earliest was an article from Myrabø et al. (1998) and three reports/guidelines from NPRA (2003, 2005, 2006).

Governmental requirements for adopting NBS

In Norway, several public sectors are involved in and provide requirements and support for implementing nature-based solutions. These efforts relate mainly to climate change mitigation and adaptation or stormwater treatment, but also to Norway's commitment to the EU Water Framework Directive and the UN Sustainable Development Goals.

Since 2005, the Norwegian Public Road Administration (NPRA) used nature-based sedimentation ponds and infiltration solutions for treating road runoff. Treatment measures is required for state roads with certain traffic volume levels depending on recipient vulnerability, and specific NBS is listed as relevant measures in their handbooks for road construction (Norwegian Public Road Administration, 2005; 2011; 2014; 2018; Norwegian Public Road Administration, 2021) – handbooks which are founded on Norwegian law.

Conservation and restoration of bogs and other wetlands are considered important for climate change mitigation (Ministry of Climate and Environment, 2021).

---

28. Norwegian Environment Agency, Norwegian Agriculture Agency, Directorate of Fisheries, Norwegian Water Resources and Energy Directorate, Norwegian Public Road Administration, Norwegian Building Authority, Directorate for Civil Protection and Emergency Planning, and County Governors.
29. Including Oslo which shares administration with the municipality.
30. Geographic spread: Northern Norway (2), Central Norway (4), Western Norway (5), Southern Norway (2), Eastern Norway (7).
31. In some cases, the publications used other terms instead of "solutions" like methods or climate adaptation or added terms like stormwater or treatment, e.g., nature-based climate adaptation, nature-based blue-green structures and nature-based sedimentation pond. Two documents using the term blue-green (stormwater) solutions were included in the matrix, of which one was relevant (because it mentioned known NBS) while the other one was irrelevant.

Therefore, new cultivation of bogs is not allowed, and the government is considering additional measures (i.e., regulation, fees) to reduce degradation of bogs, whilst restoring already degraded bogs.

Most of the work on NBS in Norway relates to climate adaptation. For land-use planning, the Ministry of Climate and Environment and Ministry of Local Government and Modernisation adopted a legally binding governmental planning guideline for climate and energy planning and climate adaptation (2018), which states that:

"Conservation, restoration or establishment of nature-based solutions (such as existing wetlands and natural streams or new green roofs and walls, artificial streams and pools, etc.) should be considered. If other solutions are chosen, it must be justified why nature-based solutions have been chosen away". (§4.3)

This means that municipal, regional and state authorities are not obliged to implement NBS but have to consider them in land-use planning. If NBS are not chosen, they need to justify why. The County Governors and other state agencies like NVE often address the need to consider NBS for climate adaptation in their consultation response to local zoning plans and other planning processes in case they were not considered by the municipalities.

Looking at municipal master plans and detailed zoning plans in several municipalities, it is evident that some municipalities have taken the governmental planning guidelines into account, while little evidence for that was found in other municipalities. For instance, according to a draft of a new land-use strategy, the City of Stavanger (2021) will *"preserve and further develop Stavanger's green structure. [...] The green structure must be coherent, nearby, varied and nature-based".* Furthermore, several of Stavanger's detailed zoning plans and planning programmes require using NBS when possible/appropriate to manage stormwater locally.

Table 10. Governmental requirements for adopting NBS from the national authorities in Norway.

National authorities	Environment and climate	Primary industries	Land-use planning	Infrastructure
Laws and regulations		Ban on new cultivation on/in bogs[1,2]	For climate adaptation, conservation, restoration or NBS should be considered[3]	Consider road runoff treatment with NBS (instead of technical treatment options)[4]
Policies, strategies and plans	Restoration of at least 15% of deteriorated watercourses[5] Continued restoration of bogs and other wetlands; development of a national strategy to prevent bog degradation.[1] Continued establishment of marine protected areas (MPAs); national plan for MPAs; assess additional protection of rare natural values in the deep sea.[6] Promotion of NBS via UNEA; more NBS within the water and wastewater sector[7] Increased focus on NBS to solve the climate crisis including carbon storage on topsoil, forests and kelp forest.[8]	The government considers prohibition of new peat extraction.[1]	High importance of climate change adaptation through NBS[3, 9] Assess introduction of a fee on greenhouse gas emissions from land-use changes.[1]	

References:
[1] White Paper 13 (2020–2021): Climate plan for 2021–2030 (Ministry of Climate and Environment, 2021)
[2] Regulations on new cultivation (Ministry of Agriculture and Food, 2020)
[3] Governmental planning guidelines for climate and energy planning and climate adaptation (Ministry of Climate and Environment; Ministry of Local Government and Modernisation, 2018)
[4] N200 Road construction - Road standard N200 (Norwegian Public Road Administration, 2021)
[5] More viable watercourses: Proposal - national strategy for restoration of watercourses 2021–2030 (Directorate group for water management, 2022)
[6] White Paper 29 (2020–2021): Comprehensive national plan for the conservation of important areas for marine nature (Ministry of Climate and Environment, 2021)
[7] Action plans to achieve the sustainability development goals by 2030 (Ministry of Local Government and Modernisation, 2021)
[8] The Hurdal platform is an agreement between the sitting political parties about their priorities in government. (The Office of the Prime Minister, 2021)
[9] Strategy for small towns and larger towns such as regional power centers (Ministry of Local Government and Modernisation, 2021)

Table 11. Governmental requirements for adopting NBS from regional authorities in Norway. The county authorities in all regions were targeted.

Regional authorities	Environment and climate	Primary industries	Land-use planning	Infrastructure
Laws and regulations				
Policies, strategies and plans			Rogaland County states that NBS must be the first choice for further development.[1] Municipalities should pay special attention to blue-green structures including connection of green nature areas and open waterways (County Governor of Oslo/Viken)[2]	New developments must consider use of NBS to conserve ecosystem services; required to meet the need for fauna passages, wildlife corridors and passages.[3] (Viken County)

References:
[1] Regional plans for climate adaptation in Rogaland 2020–2050 (County authority of Rogaland, 2020)
[2] The County Governor of Oslo and Viken's expectations for municipal spatial planning in 2022 (County Governor of Oslo and Viken, 2021)
[3] Transport Strategy 2022–2033 (County authority of Viken, 2020)

Table 12. Governmental requirements for adopting NBS from local authorities in Norway.
Note that only a limited number of municipalities were targeted. Note that only a limited number of municipalities were targeted – 5 municipalities with the most inhabitants, while 15 municipalities were randomly chosen.

Local authorities	Environment and climate	Primary industries	Land-use planning	Infrastructure
Laws and regulations			City of Stavanger: Stormwater shall mainly be managed through NBS.[1, 2] In a specific area of Hemsedal municipality, local NBS will be planned in sparsely developed areas without common sewers.[3]	
Policies, strategies and plans			The City of Stavanger (according to a proposition, not yet adopted) will *"preserve and further develop Stavanger's green structure. [...] The green structure must be coherent, nearby, varied and nature-based"*[4] In their stormwater strategy, the City of Bærum adopted an overarching principle for developing areas stating that "there should be more use of nature-based and multifunctional stormwater solutions".[5]	

References:
[1] Municipal master plans for Stavanger 2019–2034: Regulations and guidelines (land-use part) (City of Stavanger, 2019). In 2020, Stavanger municipality was merged with three additional municipalities (Finnøy, Rennesøy and parts of Hjelmeland). This document is still legally binding until a new plan have been adopted.
[2] Municipal master plans for Finnøy municipality 2019–2029: Provisions, guidelines and tables (Finnøy municipality, 2019)
[3] Markegardslia-Lykkja: Municipal sector plan 2015–2027 Hemsedal municipality: Forecasts and guidelines (Hemsedal municipality, 2015)
[4] Proposed area strategy for the City of Stavanger - the area element of the municipal master plan 2023–2040 (City of Stavanger, 2021)
[5] Stormwater: from problem to resource! Strategy for stormwater management 2017–2030 (City of Bærum, 2017)

Support provided to facilitate NBS

Public authorities
Most of the identified Norwegian NBS supporting material targeted climate adaptation, stormwater management and road runoff treatment – not implementation and management of NBS specifically. The use of NBS is, however, often suggested as a solution to these societal challenges. In-depth guidance and information about different NBS were mainly provided in two documents, namely a report on water protection in the road sector providing details about NBS and technical solutions for runoff treatment (Norwegian Public Road Administration, 2014), and a report on NBS for climate adaptation providing descriptions, examples and analysis of different kinds of NBS (Magnussen, et al., 2017).

Public authorities also provided supporting material for the governance processes related to climate adaptation and stormwater management with details about relevant requirements and policy tools. These documents often mention NBS briefly or in dedicated sub-chapters but are rarely about NBS exclusively. Examples are a report on integration of NBS for climate change mitigation and adaptation in national management (Norwegian Environment Agency, 2018), and several guidance documents and tools targeting land-use planners working on climate adaptation (County authority of Rogaland, 2021; Norwegian Environment Agency, 2019; 2019;

2021; 2021) or stormwater and flood management (Norwegian Environment Agency, 2019; Norwegian Water Resources and Energy Directorate, 2022). For treatment of contaminated soil, the Norwegian Environment Agency (NA) only briefly mentioned NBS for in-situ treatment of contaminated soil in a guideline on the topic.

National authorities and municipalities also gathered knowledge through commissions to support governance processes. Identified reports related to knowledge about the NBS themselves (Magnussen, et al., 2017), mapping needs for knowledge, guidance and user support (Aanderaa, et al., 2021), or specific topics like biodiversity restoration in urban sea areas (Rinde, et al., 2019) or mass fillings in sea as nature-enhancing measures (Rinde, Sørensen, & Haraldsen, 2019).

In terms of financial support, there is a regional environmental subsidy for agriculture in which nature-based treatment solutions for climate adaptation are eligible for funding (Norwegian Agriculture Agency, 2020). The Norwegian Environment Agency also provide grants annually to municipalities and county authorities for knowledge building projects and assessments about climate adaptation measures. Several projects that received funding in 2021 were related to NBS and restoration efforts (Norwegian Environment Agency, 2021).

Table 13. Support material provided to facilitate NBS planning, implementation and management by national public authorities in Norway.

Material resulting from commissions from the public authorities is sorted under the actor who commissioned the projects.

National authorities	Environment and climate	Primary industries	Land-use planning	Infra-structure
Guidelines and tools	Overview of regulations and framework conditions for municipal stormwater management, with an own chapter on NBS for stormwater management.[1]	Guide on planning green structures in cities and towns[2]. Guide to the governmental planning guidelines for climate adaptation, with support material on how to consider NBS in planning.[3] Guide on stormwater management in land-use planning.[4]	Guide on water protection through treatment methods (including NBS) in road construction, which for each method includes principle drawings, information on specific procedural conditions, design and dimensioning, operation, experiences and treatment effects.[5]	
In-depth knowledge targeting practitioners and public administration	Report about existing means and measures for how NBS for climate change mitigation and adaptation may be better integrated in national management.[6] Reports commissioned by national authorities:Report on NBS for climate adaptation, which includes descriptions and assessment of different kinds of NS, examples and analyses, and a comparison of NBS versus other solutions.[7] Mapping of the public administration's need for knowledge, guidance and user support for implementing NBS for climate adaptation[8]			
General information for the public (e.g., webpages, fact sheets)	Information page on climate adaptation and measures to safeguard biodiversity and outdoor life in a changing climate, with descriptions and examples of NBS and reference to relevant guides and resources.[9] Fact sheet on nature as a climate solution[10]			

References:

[1] How to handle stormwater: Overview of regulations and framework conditions for the municipality's handling of stormwater. (Norwegian Environment Agency, 2021)
[2] Green structure close to cities and towns in land-use planning (Norwegian Environment Agency, 2021)
[3] How to take climate change into account in planning? (Norwegian Environment Agency, 2019)
[4] Guideline for handling stormwater in land-use plans: How account for water volumes? (Norwegian Water Resources and Energy Directorate, 2022)
[5] Water protection in road planning and road construction (Norwegian Public Road Administration, 2006; 2014)
[6] Nature-based solutions for climate challenges in national management (Norwegian Environment Agency, 2018)
[7] Nature-based solutions for climate adaptation (Magnussen, et al., 2017)
[8] The solution is nature-based: A mapping of the public administration's needs for user support regarding nature-based solutions for climate adaptation (Aanderaa, et al., 2021)
[9] Nature and recreation: Climate adaptation and measures to safeguard biodiversity and outdoor life in a changing climate. (Norwegian Environment Agency, 2021)
10 Nature as a climate solution (Fremstad, 2019)

Table 14. Support material provided to facilitate NBS planning, implementation and management by regional authorities in Norway.
Material resulting from commissions from the public authorities is sorted under the actor who commissioned the projects. The county authorities in all regions were targeted.

Regional authorities	Environment and climate	Primary industries	Land-use planning	Infrastructure
Guidelines and tools			A process guide for work with nature-based solutions for climate adaptation in Rogaland[1]	
In-depth knowledge targeting practitioners and public administration			NBS was briefly mentioned in knowledge reports supporting the planning process of: Regional plan for climate adaptation in Rogaland 2020–2050[2] Regional transportation plan 2018–2027 in Sogn and Fjordane[3]	
General information for the public				

References:
[1] Nature-based solutions for climate adaptation: A process guide for work with nature-based solutions for climate adaptation in Rogaland (County authority of Rogaland, 2021)
[2] Knowledge part: Regional plan for climate adaptation in Rogaland 2020–2050 (County authority of Rogaland, 2020)
[3] Regional transport plan 2018–2027: Knowledge basis (County authority of Sogn and Fjordane, 2017). The county was merged with several other counties into the County of Vestland in 2020.

Table 15. Support material provided to facilitate NBS planning, implementation and management by local authorities in Norway.

Material resulting from commissions from the public authorities is sorted under the actor who commissioned the projects. Note that only a limited number of local authorities were targeted – 5 municipalities with the most inhabitants, while 15 municipalities were randomly chosen.

Local authorities	Environment and climate	Primary industries	Land-use planning	Infra-structure
Guidelines and tools				
In-depth knowledge targeting practitioners and public administration	Commissioned by municipalities: Report on restoration of biodiversity in urban sea areas (Oslo)[1] Report on mass fillings in sea as nature-enhancing measures (Bærum)[2]			
General information for the public			City of Oslo: Interview with an engineer describing what happens when Oslo gets its extreme rainfalls – and how the municipality is addressing it. NBS is briefly mentioned as a solution.[3] Grenland region: Information about climate and climate adaptation (incl. NBS) in the Grenland municipalities.[4]	

References:
[1] Restoration of biological diversity of Oslo's urban sea areas (Rinde, et al., 2019)
[2] Statement and recommendations on plans for establishing new landscapes at Lakseberget and Telenor beach at Fornebu (Rinde, Sørensen, & Haraldsen, 2019)
[3] Stormwater management (City of Oslo, n.d.)
[4] What happens when Oslo gets its extreme rainfalls? (City of Oslo, 2017)5 (Environment and health in Grenland, n.d.)

Knowledge providers

Norwegian academic institutes, consultancies and interest organisations provide support to public authorities by developing and providing knowledge about NBS and its management, sometimes in collaboration projects and sometimes commissioned by the authorities. As part of their education, some also wrote their master thesis on NBS.

Tools and other resources have been developed by KLIMA2050, a Centre for Research-based Innovation (SFI) focusing on climate adaptation of buildings and infrastructure – among other checklists, toolbox for landslide risk mitigation, and NBS documentation tool (Raspati, Bruaset, Sivertsen, Møller-Pedersen, & Røstum, 2019; Andenæs, Time, Muthanna, & Kvande, 2022; Sivertsen, et al., 2021; Capobianco, 2020). Moreover, Pulg et al. (2020) is developing methods (including a model tool) to safeguard better flood protection and the environmental condition of watercourses.

Identified knowledge synthesis was about NBS as landslides safety measures (Kalsnes & Capobianco, 2019), or road runoff treatment measures (Sivertsen, Raspati, Barrio, Bruaset, & Azrague, 2021). Moreover, Hancke et al. (Hancke, et al.,

2021) studied the environmental impacts of kelp cultivation, while Skrindo & Mehlhoop (2021) experimented with natural revegetation from local top masses to ease negative effects of road construction on biodiversity. Handberg et al. (2020) synthesised knowledge and identified knowledge gaps concerning climate adaptation, in which they identified limited experience with NBS resulting in knowledge gaps related to the effectiveness and costs of NBS.

Lastly, quite a few Norwegian reports included recommendations for management, often by first summarizing the current status and challenges. These reports were related to river restoration (Nesheim, Moe, Ranneklev, & Furuseth, 2020), marine protection (Jørgensen, et al., 2021), efforts for coastal cods (Moland, et al., 2021), and road runoff treatment measures (Myrabø & Roseth, 1998). Brendehaug et al. (2021) studied interaction effects of climate and environment policies in management, namely synergies and side effects of several NBS for climate change mitigation and adaptation (e.g., conservation and implementation of blue-green structures, green roofs and walls, urban horticulture, natural forest and wetlands). They recommended raising the level of knowledge among elected officials, sharing knowledge and experience with NBS, making requirements for NBS clearer, and allowing trial and error in implementing NBS.

Table 16. Support material provided to facilitate NBS planning, implementation and management by academic institutions, consultancies and interest organizations in Norway.

Academic institutions, consultancies and interest organisations	Environment and climate	Primary industries	Land-use planning	Infrastructure
Guidelines and tools	Landslide Risk Mitigation Toolbox assisting user in identifying cost-effective structural landslide risk mitigation options (incl. NBS).[1] Handbook providing an NBS impact assessment framework, including indicators and methods to assess impacts of NBS.[2]		Guideline for a documentation tool consisting of 'data structure' allowing asset managers to register useful and necessary information of NBS.[3] Checklist for planning blue-green roofs in building applications.[4] Checklist for the planning and construction process of reopening streams.[5]	

In-depth knowledge targeting practitioners and public administration	Knowledge synthesis and feasibility study, which identified relevant measures (incl. NBS) for restoring an urban river in Oslo, Alna.[6] The Institute of Marine Research's expert assessment of challenges and status of work with marine protection (i.e., NBS) in Norway, incl. recommendations for future action.[7] Status report on efforts for coastal cod in two marine protected areas, Færder and Ytre Hvaler national parks; summarising current knowledge/status and providing recommendations for further action (incl. conservation, sustainable use and restoration measures).[8] Knowledge overview of NBS and their applicability as landslides safety measures with reference to key actors, important studies and innovation potentials.[9] Study on interaction effects of environmental and climate policies (e.g., synergies and conflicts), among other the work on NBS in public administration. It provides recommendation for further action related to climate change mitigation and adaptation, and biodiversity.[10] Book chapter about the regulating ecosystem services provided by NBS – and its potential to offset carbon emissions, reduce heat stress and abate air pollution.[11] Report identifying research needs and measures (including NBS) to improve water quality in stormwater and urban rivers and streams.[12]	Research results on the environmental impacts of kelp cultivation with recommendations to public administration on a management strategy for future monitoring of kelp facilities.[13]	Knowledge synthesis related to climate adaptation measures (incl. NBS) in the road sector, which identified knowledge gaps like effectiveness and costs of NBS.[14] Literature review on contaminated stormwater, summarising current knowledge on NBS for road runoff treatment. [15] Report on microplastics in road dust, summarising current knowledge about characteristics, pathways and measures (incl. nature-based treatment solutions).[16]
General information for the public			Article on the relevance of NBS as road runoff treatment measure, discussing relevant considerations in road development projects.[17]

References:
1 New tool can help more people choose nature-based solutions to reduce landslides and erosion risk along rivers and streams (Capobianco, 2020); https://www.larimit.com)
2 Evaluating the impact of nature-based solutions (European Commission, Directorate-General for Research and Innovation, 2021)
3 Documentation tool of nature-based solutions – a guideline (Raspati, Bruaset, Sivertsen, Møller-Pedersen, & Røstum, 2019)
4 Risk frameworks for blue-green roofs (Andenæs, Time, Muthanna, & Kvande, 2022)
5 Stream opening as a climate adaptation measure: An overall and multidisciplinary instruction (Sivertsen, et al., 2021)
6 Alna - knowledge synthesis and feasibility study (Nesheim, Moe, Ranneklev, & Furuseth, 2020)
7 Marine protection - The Institute of Marine Research's expert assessment of challenges and status of work with marine protection in Norway (Jørgensen, et al., 2021)
8 Efforts for coastal cod - Knowledge for site-adapted reconstruction of stocks, habitats and ecosystems in Færder and Ytre Hvaler national parks (Moland, et al., 2021)
9 Nature-based Solutions: Landslides Safety Measures (Kalsnes & Capobianco, 2019)
10 Interaction effects in local environmental and climate policy: Synergies and conflicts in measures to reduce greenhouse gas emissions, take care of biological diversity, climate adaptation and energy change (Brendehaug, Groven, & Selseng, 2021)
11 Assessing the Potential of Regulating Ecosystem Services as Nature-Based Solutions in Urban Areas (Baró & Gómez-Baggethun, 2017)
12 Measures to achieve improved hygienic water quality for recreational activities in storm runoff water and city rivers – pre-project to identify research needs (Tryland, et al., 2017)
13 Environmental impacts of kelp cultivation and recommendations for a management strategy (Hancke, et al., 2021)
14 Knowledge and knowledge gaps to assess the profitability of climate adaptation measures in the road sector (Handberg, Selseng, Aall, & Bruvoll, 2020)
15 Contaminated stormwater. A literature study (Sivertsen, Raspati, Barrio, Bruaset, & Azrague, 2021)
16 Microplastics in road dust – characteristics, pathways and measures (Vogelsang, et al., 2020)
17 LID-relevant issues and nature-based solutions (Myrabø & Roseth, 1998)

Ongoing research activities
Norwegian institutes carry out several national and international research activities related to NBS, sometimes collaborating with regional and local authorities, consultancies and NGOs. Mainly projects about climate adaptation are undertaken in Norway.

The Research Council of Norway provided funding for 5 ongoing national research and collaboration projects (SABICAS, NATURACT, NordSalt, BIOSPHERE, and FreshRestore), one ongoing European research project (DeSCIPHER) and an innovation arena for public authorities (received by the City of Oslo[32]), as well as several current or previous coordination and support activities (PlaNet, SECUREWater-Cities, URSA MAJOR, OCEAN2).[33] Moreover, municipalities and county authorities are partners in large EU funded projects like PHUSICOS (County authority of Innlandet, 2019), UNaLab (City of Stavanger) and BEGIN (City of Bergen) – all related to climate adaptation. In addition, the City of Oslo is part of the Edible Cities Network (EdiCitNet) which focus on NBS for urban food production. As an add-on to the PHUSICOS project, the Norwegian Environment Agency awarded funding to the County Authority of Innlandet (2020) for developing a virtual reality platform for flood and landslide prevention work.

9.1.5 Sweden

Method

The grey literature search for Sweden was conducted from January to February 2022 and included all steps except snowballing. The search was undertaken using the NBS term in Swedish, "naturbaserade lösningar". The national government (including all ministries) and several national governmental bodies were targeted. 19 regional authorities were targeted and 21 municipalities (stad/kommune). As to academic literature, six research institutes and universities were targeted, as were the national academic database, DIVA. All publications found during this exercise which included the term nature-based solutions, were added to the matrix. 186 unique documents and websites were added to the Swedish data matrix of which 76% were deemed relevant.

Governmental requirements for adopting NBS

At the national level, there is an explicit requirement to implement NBS in the agricultural ecosystem the Sweden as farmers receiving funding from EU. Common Agricultural Policy are obliged to implement ecological focus areas (e.g., flowering fallows, Salix, nitrogen-fixing crops, unused field edges etc.). For the other ecosystems, there are no governmental requirement for adopting NBS. At the regional level, there is no requirements. At the local levels, Swedish municipalities have the possibility to request the implementation of NBS in land-agreements with developer companies.

32. Project title: Sustainable stormwater management for growing city in a changing climate.
33. These projects were identified through searching for "nature-based solutions" at the website of the Research Council of Norway: https://www.forskningsradet.no

Support provided to facilitate NBS

Public authorities

Several national public authorities have published reports that include NBS. In total, the study identified nine public authorities: The Swedish Environmental Protection Agency (EPA), The National Board of Housing, Building and Planning, The Swedish Transport Administration, The Swedish Geotechnical Institute, Swedish Meteorological and Hydrological Institute (SMHI), The Swedish Civil Contingencies Agency, The Swedish Forest Agency, County Administrative Boards. The most comprehensive report is the "Nature-based solutions – a tool for climate adaptation" published by the Swedish EPA in 2021. In the report, the NBS concept is defined and explained. The report also includes a guideline for implementing NBS and a collection of examples of implemented NBS in different land use contexts (urban, freshwater (wetlands), coastal, forest and agriculture) are given. The other authorities include to a varying degree the NBS concept, but the main concepts of these publications are not NBS, but ecosystem services, green infrastructure, climate change adaptation, biodiversity etc. For example, The Swedish Meteorological and Hydrological Institute (SMHI) has, together with Stockholm municipality, published a report about climate adaptation through green infrastructure in Nordic cities (Persson, Wikberger, & Amorim, 2018).

Several guidelines have been published intending to explain and steer the use of NBS in terms of examples, tools and information about NBS to solve different societal challenges. Most guidelines have been published by the National Board of Planning and Building focus on the urban and artificial ecosystems and different types of challenges that can be solved by using NBS. NBS is often not the main concept used in the guidelines, but instead green infrastructure and ecosystem services. They also provide examples of implemented NBS projects in relation to flooding, water purification, local climate regulation, erosion, and noise regulation (Boverket, 2021). Other actors have also published guidelines, for example The County Administrative Board in Västra Götaland has published a handbook about NBS and flooding (Länsstyrelsen Västra Götalands län, 2018).

There are some national policy documents that have been published that include NBS. The Swedish Civil Contingencies Agency has published a risk management plan for flooding mentioning NBS as a measure (SGI and MSB, 2020), and the County Administrative Board in Skåne has developed several risk management plans for municipalities mentioning NBS as well as an Action plan for green infrastructure 2019 – 2030 also including NBS.

Several public authorities have provided funding for different projects that include the use of NBS. This includes greening activities in cities, such as planting trees in school yards, and the implementation of wetlands to handle stormwater and improve water quality both in urban and peri-urban environments. However, these funding opportunities have not been tagged with NBS, but generally with urban green space, green infrastructure, water quality etc.

The public authorities are also engaging with academia in different context. From being part of reference groups in research projects to funding research within the context of NBS. As the concept is relatively new in Sweden, most research funding has been under the umbrella of other concepts such as ecosystem-services, green infrastructure, climate adaptation.

The regional authorities have not published much about NBS. The Region Västra Götaland have together with PE Teknik & Arkitektur and Lund University published a report from a research project studying financial instruments for NBS to reduce flood and drought risks (Ternell et al., 2019). Region Skåne is also part of an EU project called Life Coast Adapt where six municipalities in Skåne are testing methods (nature-based) to stop the negative effects of coastal erosion (Region Skåne, n.d.).

The NBS is also a relatively new concept in Sweden's 290 municipalities. Only a few municipalities are engaging with the concepts in strategic planning documents, guidelines or other written or web-based material. These documents are all new, and only the plan from Kristianstad municipality (Nature-based coastal protection) have a clear focus on the NBS concept in the title. However, many Swedish municipalities have an ongoing work with different types of NBS to solve societal challenges involving the development of strategic plans and planning tools to facilitate the implementation of NBS in the planning process. This includes green plans, tree plans, nature conservation plans, climate adaptation plans, as well as guidelines, checklists to structure the work with urban green space in the planning process.

References Appendix 1

Aktuelt Naturvidenskab. (2020). Klimatilpasning – fra tanke til handling. Retrieved from: https://aktuelnaturvidenskab.dk/find-artikel/nyeste-numre/2-2020/klimatilpasning

Andenæs, E., Time, B., Muthanna, T., & Kvande, T. (2022). *Risikorammeverk for blågrønne tak*. Klima2050. Retrieved from: https://www.sintefbok.no/book/index/1317/risikorammeverk_for_blaagroenne_tak

Auvinen, A.-P., Kemppainen, E., Jäppinen, J.-P., Heliölä, J., Holmala, K., Jantunen, J., Koljonen, M.-L., … Ahlroth, p. (2020). *Suomen biodiversiteettistrategian ja toimintaohjelman 2012–2020 toteutuksen ja vaikutusten arviointi. Valtioneuvoston selvitys- ja tutkimustoiminnan julkaisusarja* 2020:36. Retrieved from: http://urn.fi/URN:ISBN:978-952-287-915-8

Boverket (2021). *Gröna lösningar för ekosystemtjänster i praktiken.* Retrieved from: https://www.boverket.se/sv/PBL-kunskapsbanken/teman/ekosystemtjanster/praktiken/

Brendehaug, E., Groven, K., & Selseng, T. a. (2021). *Samspeleffektar i lokal miljø- og klimapolitikk: Synergiar og konfliktar ved tiltak for reduksjon av klimagassutslepp, varetaking av biologisk mangfald, klimatilpassing og energiomstilling.* Vestlandsforskning. Retrieved from: https://vestforsk.no/sites/default/files/2021-08/Samspeleffektar%20VF-rapport%204-2021%20MASTERDOKUMENT.pdf

Capobianco, V. E. (2020). Nytt verktøy kan bidra til at flere velger naturbaserte løsninger for å redusere skred og erosjonsfare langs elver og bekker. VANN. Retrieved from: https://vannforeningen.no/wp-content/uploads/2020/10/Capobianco.pdf

City of Bærum. (2017). Overvann: fra problem til ressurs! Strategi for overvannshåndtering 2017–2030. *Stormwater: from problem to resource! Strategy for stormwater management 2017–2030*. Bærum, Norway. Retrieved from: https://www.baerum.kommune.no/globalassets/tjenester/vann-og-avlop/klima-og-miljo/overvannsstrategi-barum-kommune.pdf

City of Oslo. (2017). *Hva skjer når Oslo får sitt ekstremregn?* Norway: Oslo kommune. Retrieved from: https://magasin.oslo.kommune.no/byplan/hva-skjer-nar-oslo-far-sitt-ekstremregn

City of Oslo. (n.d.). *Overvannshåndtering.* Oslo, Norway: Oslo kommune. Retrieved from: https://www.oslo.kommune.no/vann-og-avlop/arbeider-pa-vann-og-avlopsnettet/overvannshandtering/

City of Stavanger. (2019). Kommuneplan for Stavanger 2019 – 2034: Bestemmelser og retningslinjer (arealdel). *Municipal master plan 2019–2034: Regulations and guidelines (land-use part). Former Stavanger municipality*, Norway. Retrieved from: https://www.stavanger.kommune.no/siteassets/samfunnsutvikling/planer/kommuneplan/arealdel-stavanger-2020/vedlegg-02-bestemmelser-og-retningslinjer-ny.pdf

City of Stavanger. (2021). *Forslag til arealstrategi for Stavanger kommune - kommuneplanens arealdel 2023–2040*. Retrieved from: https://www.stavanger.kommune.no/stavanger2040/nyhetsutlisting/arealstrategien/

County authority of Innlandet. (2019). *Internasjonale prosjekter.* Retrieved from: https://innlandetfylke.no/tjenester/naring-og-internasjonalt/internasjonalt-samarbeid/internasjonale-prosjekter/

County Authority of Innlandet. (2020). *500 000 til VR-prosjekt mot flom.*

County authority of Rogaland. (2020a). *Kunnskapsdel: Regionalplan for klimatilpasning i Rogaland 2020–2050.* Rogaland, Norway: Rogaland fylkeskommune. Retrieved from: https://www.rogfk.no/_f/p1/i7fc8b89b-1823-4c14-a093-8309f18a34ce/kunnskapsdel_rp_klimatilpasning_vedtatt-201020.pdf

County authority of Rogaland. (2020b). R*egionalplan for klimatilpasning i Rogaland 2020–2050.* Retrieved from: https://www.rogfk.no/_f/p1/i0546ef8d-c1b6-4b97-abec-6f8ba8775152/regionalplan-for-klimatilpasning-i-rogaland-2020-2050.pdf

County authority of Rogaland. (2021). *Naturbaserte løsninger for klimatilpasning: En prosessveileder for arbeid med naturbaserte løsninger for klimatilpasning i Rogaland.* Rogaland, Norway: Rogaland fylkeskommune. Retrieved from: https://www.rogfk.no/vare-tjenester/planlegging/veiledning-i-planarbeidet/natur-klima-og-miljo/naturbaserte-losninger/

County authority of Sogn and Fjordane. (2017). *Regional transportplan 2018–2027: Kunnskapsgrunnlag.* Sogn og Fjordane, Norway: Sogn og Fjordane fylkeskommune. Retrieved from: https://www.sfj.no/kunnskapsgrunnlag.407704.nn.html

County authority of Viken. (2020). Samferdselsstrategi 2022–2033. T*ransport Strategy 2022–2033.* Viken, Norway: Viken fylkeskommune. Retrieved from: https://viken.no/tjenester/vei-og-kollektiv/samferdselsplanlegging/planer-og-strategier/samferdselsstrategi-2022-2033/

County Governor of Oslo and Viken. (2021). *Statsforvalteren i Oslo og Vikens forventninger til kommunal arealplanlegging 2021.* Retrieved from: https://www.statsforvalteren.no/nb/oslo-og-viken/plan-og-bygg/sideoppbevaring/forventninger-til-kommunal-planlegging/

Danske regioner. (2022). Vandet kommer: *Danske Regioners syv anbefalinger til en national klimatilpasningsplan.* Retrieved from: https://edagsorden.regionh.dk/cms/HtmlPublication-7327/enclosures/10.pdf

Dinesen, L., Petersen, A.H. Rahbek. (2021). *Synergi in conservation of biodiversity and* *climate change mitigation – Nordic peatlands and forests.* Nordic council of Ministers. Retrieved from: http://norden.diva-portal.org/smash/record.jsf?pid=diva2%3A1546444&dswid=-6850

Directorate group for water management. (2022). *Mer livskraftige vassdrag: Forslag - nasjonal strategi for restaurering av vassdrag 2021–2030*. Retrieved from: https://www.vannportalen.no/kunnskapsgrunnlaget/restaurering-av-vassdrag/restaureringsstrategien/

DTU (2022). *Inklusion af regnbede i SCALGO Live ved kobling til DTUs LAR-potentialeberegner.* Retrieved from: https://water.dtu.dk/VIS/Projektbeskrivelser/Scalgo

Environment and health in Grenland. (n.d.). Klima. Skien, Porsgrunn, Bamble, Kragerø, Drangedal, Siljan, Grenland. Norway: Miljø og helse i Grenland. Retrieved from: https://miljooghelsegrenland.no/kategori/klima/

EU2019.FI - Finland's Presidency of the Council of the European Union (n.d.). *EU preparations for UN biodiversity targets.* Retrieved from: https://eu2019.fi/en/backgrounders/eu-preparations-for-un-biodiversity-targets

European Commission, Directorate-General for Research and Innovation. (2021). *Evaluating the impact of nature-based solutions: a handbook for practitioners.* Publications Office. Retrieved from: https://data.europa.eu/doi/10.2777/244577

European Environment Agency. (2021). *Nature-based solutions in Europe: Policy, knowledge and practice for climate change adaptation and disaster risk reduction.* European Environment Agency. Retrieved from: https://www.eea.europa.eu/publications/nature-based-solutions-in-europe

Finnøy municipality. (2019). Kommuneplan for Finnøy kommune 2019–2029: Føresegner, retningslinjer og tabellar. *Municipal master plans for Finnøy municipality 2019–2029: Provisions, guidelines and tables. Finnøy, Norway.* Retrieved from: https://www.stavanger.kommune.no/siteassets/samfunnsutvikling/planer/kommuneplan/arealdel-stavanger-2020/kmd-finnoy-desember-2020/kpa-finnoy-foresegner-vedtatt-07.10.-2019-kmd-28.11.2020.pdf

Foreningen Hunderevet. (2019). *Stenrev i kystzonen.* Retrieved from: https://mim.dk/media/218055/stenrev_i_kystzonen_-_natur_og_biodiversitetspakken.pdf

Fremstad, J. (2019). Naturen som klimaløsning. Norway: Miljødirektoratet. Retrieved from: http://hdl.handle.net/11250/2603127
Government of Iceland. (2021). *Increased efforts for climate adaptation, nature-based solutions.* Retrieved from: https://www.government.is/diplomatic-missions/embassy-article/2021/01/28/Increased-efforts-for-climate-adaptation-nature-based-solutions/

Green Cities Denmark (2021). Klimakampen, *12 løsninger til håndtering af regnvand.* Retrieved from: https://thegreencities.eu/wp-content/uploads/2021/11/Klimakamp-

WEB-v2.pdf

Hancke, K., Broch, O. J., Olsen, Y., Bekkby, T., Hansen, P. K., Fieler, R., . . . Borgersen, G. C. (2021). *Miljøpåvirkninger av taredyrking og forslag til utvikling av overvåkingsprogram.* Norway: Norwegian Institute for Water Research (NIVA). Retrieved from: https://hdl.handle.net/11250/2731345

Handberg, Ø. N., Selseng, T., Aall, C., & Bruvoll, A. (2020). *Kunnskap og kunnskapshull for å vurdere lønnsomhet av klimatilpasningstiltak i veisektoren*. Western Norway Research Institute. Retrieved from: https://vestforsk.no/nn/publication/kunnskap-og-kunnskapshull-vurdere-lonnsomhet-av-klimatilpasningstiltak-i-veisektoren

Hemsedal municipality. (2015). *Markegardslia-Lykkja: Kommunedelplan 2015–2027 Hemsedal kommune – Føresegner og retningsliner.* Norway.

JA Aktuelt. (2021). *Naturbaserede løsninger i det regenerative landbrug.* Retrieved from: https://www.jaaktuelt.dk/artikler/2021/naturbaserede-loesninger-i-det-regenerative-landbrug/

Jørgensen, L. L., Moland, E., Husa, V., Kutti, T., Kleiven, A. R., & van der Meeren, G. I. (2021). *Marint vern - Havforskningsinstituttets ekspertvurdering av utfordringer og status for arbeid med marint vern i Norge.* Havforskningsinstituttet. Retrieved from: https://hdl.handle.net/11250/2739666

Kalsnes, B., & Capobianco, V. (2019). Nature-based Solutions: *Landslides Safety Measures.* SINTEF. Retrieved from: http://hdl.handle.net/11250/2617166

Klimamonitor. (2022). *Arkitektforskere: Drop højvandsmurene og brug i stedet naturbaseret klimasikring.* Retrieved from: https://klimamonitor.dk/debat/art8611878/Drop-h%C3%B8jvandsmurene-og-brug-i-stedet-naturbaseret-klimasikring

Klimarådet (2020). *Kulstofrige lavbundsjorder.* Klimarådet, Copenhagen, 49 pp. Retrieved from: https://klimaraadet.dk/da/analyser/kulstofrige-lavbundsjorder

Luke (n.d.). Open-air laboratories for nature-based solutions to manage environmental risks. OPERANDUM. Retrieved from: https://www.luke.fi/projektit/operandum/

Länsstyrelsen Västra Götaland (2018). Naturbaserade lösningar mot översvämning. Retrieved from: https://www.lansstyrelsen.se/publikation?entry=O_2018__3&context=13

Magnussen, K., Wifstad, K., Seeberg, A., Stålhammar, K., Bakken, S., Banach, A., . . . Sandsbråten, K. (2017). *Naturbaserte løsninger for klimatilpasning.* Norway: Miljødirektoratet. Retrieved from: https://www.miljodirektoratet.no/publikasjoner/2017/oktober-2017/naturbaserte-losninger-for-klimatilpasning/

Ministry of Agriculture and Food. (2020). Forskrift om nydyrking.

FOR-1997-05-02-423. Norway: Landbruks- og matdepartementet.

Ministry of Agriculture and Forestry of Finland (2019). *Kansallinen metsästrategia 2025 – päivitys*. Maa- ja metsätalousministeriön julkaisuja 2019:7. Retrieved from: http://urn.fi/URN:ISBN:978-952-453-889-3

Ministry of Agriculture and Forestry of Finland (2021). *Building a climate-resilient Europe – Commission published a new EU Strategy on Adaptation to Climate Change*. Press release. https://mmm.fi/en/-/building-a-climate-resilient-europe-commission-published-a-new-eu-strategy-on-adaptation-to-climate-change

Ministry of Climate and Environment. (2021). *Meld. St. 13* (2020–2021) Klimaplan for 2021–2030. Klima- og miljødepartementet. Retrieved from: https://www.regjeringen.no/no/dokumenter/meld.-st.-13-20202021/id2827405/

Ministry of Climate and Environment. (2021). Meld. St. 29 (2020–2021) Heilskapleg nasjonal plan for bevaring av viktige område for marin natur. White Paper 29 (2020–2021): *Comprehensive national plan for the conservation of important areas for marine nature.* Norway. Retrieved from: https://www.regjeringen.no/no/dokumenter/meld.-st.-29-20202021/id2843433/

Ministry of Climate and Environment; Ministry of Local Government and Modernisation. (2018). *Statlige planretningslinjer for klima- og energiplanlegging og klimatilpasning.* Retrieved from: https://www.regjeringen.no/no/dokumenter/statlige-planretningslinjer-for-klima--og-energiplanlegging-og-klimatilpasning/id2612821/

Ministry of Local Government and Modernisation. (2021). *Mål med mening — Norges handlingsplan for å nå bærekraftsmålene innen 2030.* Retrieved from: https://www.regjeringen.no/no/dokumenter/meld.-st.-40-20202021/id2862554/

Ministry of Local Government and Modernisation. (2021). *Strategi for småbyer og større tettsteder som regionale kraftsentre.* Retrieved from: https://www.regjeringen.no/no/dokumenter/strategi-for-smabyer-og-storre-tettsteder-som-regionale-kraftsentre/id2862406/

Ministry of the Environment and Natural Resources. (2021). On the Path to Climate Neutrality - Iceland's Long-term Low Emission Development Strategy. Retrieved from: https://www.stjornarradid.is/library/02-Rit--skyrslur-og-skrar/Iceland_LTS_2021.pdf

Ministry of the Environment of Finland (2019). *Undersökning: I Finland finns det goda förutsättningar att utnyttja naturbaserade lösningar vid anpassningen till klimatförändringarna och vid bevarandet av den biologiska mångfalden. Statsrådets utrednings- och forskningsverksamhet.* Retrieved from: https://ym.fi/-/10616/tutkimus-suomessa-hyvat-edellytykset-hyodyntaa-luontopohjaisia-ratkaisuja-ilmastonmuutokseen-sopeutumisessa-ja-luonnon-monimuotoisuuden-suojelussa

Ministry of the Environment of Finland (2020). *Sustainable recovery boosts the* *necessary transformations in society. Ympäristöministeriö.* Retrieved from: https://ym.fi/-/kestava-elvytys-vauhdittaa-yhteiskunnan-valttamattomia-murroksia?languageId=en_US

Ministry of the Environment of Finland (2021). *Den bästa insatsen för naturen 2019–2020 var Yles kampanj Pelasta pörriäinen. Ympäristöministeriö.* Retrieved from: https://ym.fi/-/paras-luontoteko-2019-2020-oli-ylen-pelasta-porriainen?languageId=sv_SE

Moland, E., Synnes, A.-E., Naustvoll, L. J., Freitas, C., Norderhaug, K. M., Thormar, J., . . . Haga. (2021). Krafttak for kysttorsken - Kunnskap for stedstilpasset gjenoppbygging av bestander, naturtyper og økosystem i Færder- og Ytre Hvaler nasjonalparker. Norway: Havforskningsinstituttet. Retrieved from: https://hdl.handle.net/11250/2725009

Myrabø, S., & Roseth, R. (1998). LOD-aktuelle problemstillinger og naturbaserte løsninger. *VANN.* Retrieved from: https://vannforeningen.no/wp-content/uploads/2015/06/1998_30841.pdf

Nesheim, I., Moe, T. F., Ranneklev, S. B., & Furuseth, I. S. (2020). *Alna – kunnskapssammenstilling og mulighetsstudie.* Norwegian institute for Water Research. Retrieved from: https://hdl.handle.net/11250/2678972

Norwegian Agriculture Agency. (2020). *Regionalt miljøtilskudd i jordbruket (RMP) – kommentarer til regelverk (Rundskrivnummer 2021/13).*

Norwegian Environment Agency. (2018). *Naturbaserte løsninger for klimautfordringer i nasjonal forvaltning.* Retrieved from: https://www.miljodirektoratet.no/publikasjoner/2018/august-2018/naturbaserte-losninger-for-klimautfordringer-i-nasjonal-forvaltning/

Norwegian Environment Agency. (2019a). *Hvordan håndtere overvann: Oversikt over regelverk og rammebetingelser for kommunens håndtering av overvann.* Retrieved from: https://www.miljodirektoratet.no/ansvarsomrader/vann-hav-og-kyst/for-myndigheter/overvannshandtering/

Norwegian Environment Agency. (2019b). *Hvordan ta hensyn til klimaendringer i plan?* Retrieved from: https://www.miljodirektoratet.no/ansvarsomrader/klima/for-myndigheter/klimatilpasning/veiledning-til-statlige-planretningslinjer-for-klimatilpasning/

Norwegian Environment Agency. (2021a). *16 klimatilpasning-prosjekter får støtte.* Retrieved from: https://www.miljodirektoratet.no/aktuelt/nyheter/2021/april-2021/16-klimatilpasning-prosjekter-far-stotte/

Norwegian Environment Agency. (2021b). *By- og tettstedsnær grønnstruktur i arealplanlegging.* Norway: Miljødirektoratet. Retrieved from: https://www.miljodirektoratet.no/ansvarsomrader/overvaking-arealplanlegging/arealplanlegging/miljohensyn-i-arealplanlegging/friluftsliv/gronnstruktur-i-arealplanlegging/

Norwegian Environment Agency. (2021c). *Hvordan håndtere overvann: Oversikt over regelverk og rammebetingelser for kommunens håndtering av overvann.* Norway: Miljødirektoratet. Retrieved from: https://www.miljodirektoratet.no/ansvarsomrader/vann-hav-og-kyst/for-myndigheter/overvannshandtering/

Norwegian Environment Agency. (2021d). *Klimatilpasning i arealplan.* Retrieved from: https://www.miljodirektoratet.no/ansvarsomrader/overvaking-arealplanlegging/arealplanlegging/miljohensyn-i-arealplanlegging/klima/naturbaserte-losninger-i-klimatilpasning-og-arealplanlegging/

Norwegian Environment Agency. (2021e). *Konsekvensutredninger for klima og miljø [Veileder | M-1941].* Retrieved from: https://www.miljodirektoratet.no/ansvarsomrader/overvaking-arealplanlegging/arealplanlegging/konsekvensutredninger/

Norwegian Environment Agency. (2021f). *Natur og friluftsliv: Klimatilpassing og tiltak for å ivareta naturmangfald og friluftsliv i eit klima i endring. Norway: Miljødirektoratet.* Retrieved from: https://www.miljodirektoratet.no/ansvarsomrader/klima/for-myndigheter/klimatilpasning/klimatilpasning-i-sektorer/natur-og-friluftsliv/

Norwegian Environment Agency. (n.d.). *Veiledning til forurenset grunn.* Retrieved from: https://www.miljodirektoratet.no/ansvarsomrader/forurensning/forurenset-grunn/for-naringsliv/forurenset-grunn---kartlegge-risikovurdere-og-gjore-tiltak/

Norwegian Public Road Administration (2014a). *N200 Vegbygging: Normal Håndbok N200 2014.* Retrieved from: https://www.vegvesen.no/globalassets/fag/handboker/hb-n200-september-2014.pdf

Norwegian Public Road Administration (2014b). *Vannbeskyttelse i vegplanlegging og vegbygging: Statens Vegvesens rapportert Nr. 295.* Retrieved from: https://www.vegvesen.no/globalassets/fag/fokusomrader/miljo-og-omgivelser/295-rapport-redg27-10-15.pdf

Norwegian Public Road Administration (2018). *N200 Vegbygging - Vegnormal N200: 2018.* Retrieved from: https://www.vegvesen.no/globalassets/fag/handboker/hb-n200-vegbygging-juli-2018.pdf

Norwegian Public Road Administration (2021). *N200 Vegbygging - Vegnormal N200.* Retrieved from: https://store.vegnorm.vegvesen.no/svv-proj-1464925

Norwegian Public Road Administration. (2005). *N200 Vegbygging - Håndbok 018.* Retrieved from: http://hdl.handle.net/11250/2583318

Norwegian Public Road Administration. (2006). Vannbeskyttelse i vegplanlegging og vegbygging : veileder [Håndbok 261]. Norway. Retrieved from: http://hdl.handle.net/11250/194670

Norwegian Public Road Administration. (2011). *N200 Vegbygging - Håndbok 018.* Retrieved from: http://hdl.handle.net/11250/195816

Norwegian Water Resources & Energy Directorate (2022). *Rettleiar for handtering av overvatn i arealplanar: Korleis ta omsyn til vassmengder? Norway: Norges vassdrags- og energidirektorat.* Retrieved from: https://publikasjoner.nve.no/veileder/2022/veileder2022_04.pdf

Norwegian Water Resources and Energy Directorate (2018). *Sikringshåndboka.* Norway. Retrieved from: https://www.nve.no/moduler/

Odense municipality (2022). *Klimahandleplan.* Retrieved from: https://www.odense.dk/byens-udvikling/klima/klimaneutral-2030/klimahandleplan-2022/et-groennere-odense

Persson, G., Wikberger, C., & Amorim, J. H. (2018). Klimatanpassa nordiska städer med grön infrastruktur. SMHI, KLIMATOLOGI Nr 50, 2018. Retrieved from: http://urn.kb.se/resolve?urn=urn:nbn:se:smhi:diva-5021

Prime Minister (2020). *Iceland announces enhanced ambition at Climate Ambition Summit.* Retrieved from: https://www.government.is/news/article/2020/12/18/Iceland-announces-enhanced-ambition-at-Climate-Ambition-Summit/

Prime Minister. (2019). *Prime Minister's address at the Arctic Circle October 10th, 2019.* Retrieved from: https://www.government.is/news/article/2019/10/10/Prime-Ministers-address-at-the-Artic-Circle-october-10th.-2019/

Pulg, U., Hauer, C., Flödl, P., Skoglund, H., Postler, C., Stranzl, S. F., . . . Velle, G. (2020). *Flom og miljø i et endret klima. Verktøy til en naturbasert klimatilpasning. Statusrapport 2020.* Retrieved from: https://hdl.handle.net/11250/2726730

Quintana C.O., Kristensen E., Petersen S.G.G. (2021). Kystsikring og tilpasning til stigende havvandstand: økologiske konsekvenser og innovative løsninger. Denmark: Syddansk Universitet. Retrieved from: https://realdania.dk/-/media/realdaniadk/publikationer/faglige-publikationer/kystsikring-og-tilpasning-til-stigende-havvandstand/notat_20210519_dk.pdf

Raspati, G. S., Bruaset, S., Sivertsen, E., Møller-Pedersen, P., & Røstum, J. (2019). *Documentation tool of nature-based solutions – a guideline.* Retrieved from http://hdl.handle.net/11250/2628840

Region SKåne (n.d.). *Om Life Coast Adapt.* Retrieved from: https://lifecoastadaptskane.se/om-projektet/

Rinde, E., Sørensen, E. T., & Haraldsen, T. (2019). *Anbefalinger tilknyttet planer for etablering av nye landskap ved Lakseberget og Telenor-stranda på Fornebu. En uttalelse fra et tverrfaglig fagforum opprettet av Bærum kommune.* Norway: Norwegian Institute for Water Research (NIVA). Retrieved from:

http://hdl.handle.net/11250/2624215

Rinde, E., Sørensen, E. T., Walday, M. G., Fagerli, C. W., Christie, H., Staalstrøm, A., . . . Borchgrevink, H. B. (2019). *Reetablering av biologisk mangfold i Oslos urbane sjøområder.* Norway: Norwegian Institute for Water Research (NIVA). Retrieved from: http://hdl.handle.net/11250/2631547

SGI – Statens Geologiska Institut & MSB – Mynidgheten för Sammhellsskydd och Beredskap (2021). *Riskområden för ras, skred, erosion och översvämning. Redovisning av regeringsuppdrag enligt regeringsbeslut M2019/0124/K.* Retrieved from: https://www.sgi.se/globalassets/klimatanpassning/riskomraden_slutrapport.pdf

Sivertsen, E., Bruaset, S., Bø, L. A., Johannessen, B. G., Klausen, R., Nøst, T., . . . Time, B. (2021). *Bekkeåpning som klimatilpasningstiltak: En overordnet og flerfaglig anvisning. Klima2050.* Retrieved from: https://www.sintefbok.no/book/index/1286/bekkeaapning_som_klimatilpasningstiltak_en_overordnet_og_flerfaglig_anvisning

Sivertsen, E., Raspati, G. S., Barrio, M., Bruaset, S., & Azrague, K. (2021). *Forurenset overvann. En litteraturstudie.* SINTEF. Retrieved from: https://hdl.handle.net/11250/2832992

Skrindo, A. B., & Mehlhoop, A. C. (2021). *Naturlig revegetering fra stedlige toppmasser: Erfaringer fra utvalgte vegprosjekter.* Norwegian institute for nature research. Retrieved from: https://hdl.handle.net/11250/2833981

Smaal, A. C., Ferreira, J. G., Grant, J., Petersen, J. K., & Strand, Ø. (2019). *Goods and Services of Marine Bivalves.* Springer. Retrieved from: https://hdl.handle.net/11250/2686033

State of Green. (2021). *Nature based solutions - Using rainwater as a resource to create resilient and liveable cities.* Retrieved from: https://stateofgreen.com/en/wp-content/uploads/2021/03/SoG_WhitePaper_LAR_2020_210x297_V11_WEB.pdf

SYKE - Finnish Environment Institute (2020). *The decline in natural biodiversity can be stopped.* Press release 12.5.2020. Retrieved from: https://www.syke.fi/en-US/Research__Development/The_decline_in_natural_biodiversity_can_(56955)

Ternell, A., Stigson, P., Elmqvist, E., Ohlson, J. A., Hansson, H., Nilsson, A. M. (2019). *Financial instruments for nature-based solutions to reduce risks of flooding and drought.* Project number: 103409. Retrieved from: https://www.vastarvet.se/contentassets/d0cab03f222d49358dc69097b552e2eb/project-report_bluegreen-solutions_23-dec-19.pdf

The Office of the Prime Minister. (2021). *Hurdalsplattformen.* Norway: Statsministerens kontor. Retrieved from: https://www.regjeringen.no/no/dokumenter/hurdalsplattformen/id2877252/

Tryland, I., Mæhlum, T., Wennberg, A. C., Paruch, A., Krystad, R., Paruch, L., . . .

Kvitsjøen, J. (2017). *Tiltak for å oppnå bedre hygienisk vannkvalitet til rekreasjonsformål i overvann og byvassdrag-forprosjekt for å identifisere forskningsbehov.* Norwegian institute for water research (NIVA). Retrieved from: http://hdl.handle.net/11250/2480511

Vannportalen (2018). *Vann i statlige planretningslinjer for klima- og energiplanlegging og klimatilpasning.* Norway: Vannportalen. Retrieved from: https://www.vannportalen.no/regelverk-og-foringer/statlige-retningslinjer-og-forventninger/vann-i-statlige-planretningslinjer-for-klima--og-energiplanlegging-og-klimatilpasning-2018/

Vejle municipality (2020). *Stormflodsstrategi: Stormflodsbeskyttelse der gror med byen.* Retrieved from: https://www.vejle.dk/media/35150/201202-stormflodsstrategi.pdf

Vogelsang, C., Lusher, A., Dadkhah, M., Sundvor, I., Umar, M., Ranneklev, S., . . . Meland, S. (2020). *Microplastics in road dust – characteristics, pathways and measures.* Norwegian institute for water research (NIVA). Retrieved from: http://hdl.handle.net/11250/2493537

WWF (2020). *Flere og bedre naturoplevelser til danskerne: WWF's forslag til indsatser og indhold.* Denmark: WWF. Retrieved from: https://mim.dk/media/218115/wwf_verdensnaturfondens_forslag_til_natur-_og_biodiversitetspakken.pdf

Aanderaa, T., Bruaset, S., Jensen, L. C., Paus, K.H., Rønnevik, J. S., & Sivertsen. E. (2021). *Løsningen er naturbasert: en kartlegging av forvaltningens behov for brukerstøtte innen naturbaserte løsninger for klimatilpasning.* Asplan Viak. Retrieved from: https://www.miljodirektoratet.no/publikasjoner/2021/januar-2021/losningen-er-naturbasert/

9.2 Forest ecosystem NBS evaluations

Table 17. Replicated NBS forest management experiments in Fennoscandia.

To our knowledge, so far none exist in Denmark or Iceland. Note that experiment abbreviations or names may not be official; see footnote for full names and details of the experiments.
Country = location of the experiment; Est. = year of establishing the experiment / Durat. = realized or planned duration (Long = >10 years / Unkn = length unknown or unplanned) / Type = dominant tree species (Mixed = at least 2 tree species involved).

The subsequent four columns explain applied treatments as follows: /bRete = retention trees singly or in small groups in clear cut sites / CCF = continuous-cover logging methods (gap felling with gap diameter up to about 50 m; selection felling with 30–50% logging intensity) / CWD = coarse dead wood manipulation (usually artificial snags); Fire = prescribed burning applied.

The five right-hand columns show studied taxa or other assessed aspects:
Veget. = understory vegetation, including lichens and mosses / Fungi= fungi, usually polypores / Anim. = invertebrates (usually beetles, ants or spiders) or vertebrates (usually shrews or voles, or birds) sampled / Social = aesthetic or recreational values assessed / Econ. = economic viability of the applied operations assessed.

Abbreviation	Country	Est.	Durat.	Type	Rete	CCF	CWD	Fire	Veget.	Fungi	Anim.	Social	Econ.
NaturKultur[1]	Sweden	1989	Long	Mixed		X			X			X*	X*
Härjedalen[2]	Sweden	1989	Long	Mixed		X			X				
Fagerön[3]	Sweden	1994	5 yrs	Mixed		X	X				X		
MONTA[4]	Finland	1995	12 yrs	Spruce	X	X	X		X	X	X		X
Snöberget[5]	Sweden	1997	5 yrs	Spruce		X			X	X			X
RETREE[6]	Finland	1998	4 yrs	Spruce	X				X		X		
FIRE[7]	Finland	2000	Long	Pine	X			X	X	X	X		
Medelpad-Ångermanland[8]	Sweden	2000	Unkn	Mixed	X				X				
EVO[9]	Finland	2001	Long	Spruce	X		X	X	X	X	X		
Oak forest[10]	Sweden	2001	Long	Mixed		X			X	X	X		
Deadwood creation[11]	Finland	2002	Long	Mixed			X			X			
Deadwood manipulation[12]	Finland	2003	Long	Spruce			X			X			
Hedmark[13]	Norway	2004	2 yrs	Mixed			X				X		
PuroMONTA[14]	Finland	2004	Long	Spruce		X	X		X	X	X		
Elimyssalo[15]	Finland	2005	Long	Mixed				X	X		X		
DISTDYN[16]	Finland	2009	Long	Mixed	X	X	X		X	X	X	X	X*
Eriksköp[17]	Sweden	2009	Long	Mixed		X			X				
Future Forest[18]	Sweden	2010	Long	Mixed		X		X	X	X	X		
Spruce deadwood [19]	Sweden	2011	Unkn	Spruce			X			X			
Rogberga[20]	Sweden	2012	Long	Mixed		X			X				
Effaråsen[21]	Sweden	2012	Long	Pine	X		X	X	X	X	X		X
UNEVEN [22]	Sweden	2013	Long	Spruce		X			X		X		

1 Djupström & Weslien 2019; 2 Hagner 1992; 3 Lindhe & Lindelöw 2004; 4 Kaila 1998; 5 Hedenås & Ericson 2003; 6 Matveinen-Huju et al. 2006; 7 Kouki 2013; 8 Perhans et al. 2009; 9 Vanha-Majamaa et al. 2007; 10 Götmark et al. 2005; 11 Pasanen 2017; 12 Komonen et al. 2014; 13 Fossestol & Sverdrup-Thygeson 2009; 14 Selonen & Kotiaho 2013; 15 Hekkala et al. 2016; 16 Koivula et al. 2014; 17 Drössler 2016; 18 Hägglund et al. 2015; 19 Olsson et al. 2011; 20 Drössler 2016; 21 Djupström & Weslien 2019; 22 Joelsson et al. 2017.

9.2.1 References

Djupström, L. & Weslien, J. (2019). *Forest management and biological conservation in old pine forests A long-term field experiment at Effaråsen in Sweden. Part 1:* 2012–2018. Skogforsk, arbetsrapport 1009–2019. Retrieved from: https://www.skogskunskap.se/cd_20190409085721/contentassets/d0d80a30553f4d78afaea567f7feb135/arbetsrapport-1009-2019-sve.pdf

Fossestøl, K.O. & Sverdrup-Thygeson, A. (2009) Saproxylic beetles in high stumps and residual downed wood on clear-cuts and in forest edges. *Scand.* J. For. Res. 24, 403–416. https://doi.org/10.1080/02827580903143871

Drössler, L. (2016). *Heterogen skog - för komplex för skogsbruk och tillämpad skogsforskning?* Uppsala: Southern Swedish Forest Research Centre, Sveriges lantbruksuniversitet. Fakta. Skog, 2016:9. Retrieved from: http://www.slu.se/globalassets/ew/ew-centrala/forskn/popvet-dok/faktaskog/faktaskog16/faktaskog_09_2016.pdf

Götmark, F., Paltto, H., Nordén, B. & Götmark, E. (2005). Evaluating partial cutting in broadleaved temperate forest under strong experimental control: short-term effects on herbaceous plants. *For. Ecol. Manag. 214,* 124–141. doi: 10.1016/j.foreco.2005.03.052

Hagner, M. (1992). *Biologiskt och ekonomiskt resultat i fältförsök med plockhuggning kombinerad med plantering.* Arbetsrapport 63, Sveriges Lantbruksuniversitet, Umeå, Sweden.

Hedenås, H. & Ericson, L. (2003). Response of epiphytic lichens on Populus tremula in a selective cutting experiment. *Ecol. Appl. 13,* 1124–1134. https://doi.org/10.1890/1051-0761(2003)13[1124:ROELOP]2.0.CO;2

Hekkala, A.-M., Ahtikoski, A., Päätalo, M.-L., Tarvainen, O., Siipilehto, J. & Tolvanen, A. (2016). Restoring volume, diversity and continuity of deadwood in boreal forests. *Biodivers. Conserv. 25,* 1107–1132. https://doi.org/10.1007/s10531-016-1112-z

Hägglund, R., Hekkala, A.-M., Hjältén, J. & Tolvanen, A. (2015). Positive effects of ecological restoration on rare and threatened flat bugs (Heteroptera: Aradidae). *J. Insect Conserv. 19.* 1089–1099. https://doi.org/10.1007/s10841-015-9824-z

Joelsson, K., Hjältén, J., Work, T., Gibb, H., Roberge, J.-M. & Löfroth, T. (2017). Uneven-aged silviculture can reduce negative effects of forest management on beetles. *For. Ecol. Manag. 391,* 436–445. https://doi.org/10.1016/j.foreco.2017.02.006

Koivula, M., Kuuluvainen, T., Hallman, E., Kouki, J., Siitonen, J. & Valkonen, S. (2014). Forest management inspired by natural disturbance dynamics (DISTDYN) - a long-term research and development project in Finland. *Scandinavian Journal of Forest Research, 29*, 579–592. https://doi.org/10.1080/02827581.2014.938110

Matveinen-Huju, K., Niemelä, J., Rita, H. & O'Hara, R.B. (2006). Retention-tree groups in clear-cuts: do they constitute 'life-boats' for spiders and carabids? *For. Ecol. Manag. 230*, 119–135.

Komonen, A., Halme, P., Jäntti, M., Koskela, T., Kotiaho, J. & Toivanen, T. (2014). Created substrates do not fully mimic natural substrates in restoration: the occurrence of polypores on spruce logs. *Silva Fennica 48*, 980. https://doi.org/10.14214/sf.980

Pasanen, H. (2017). Ecological effects of disturbance-based restoration in boreal forests. PhD thesis, University of Eastern Finland. Retrieved from: https://www.researchgate.net/publication/318791575_Ecological_effects_of_disturbance-based_restoration_in_boreal_forests

Perhans, K., Appelgren, L., Jonsson, F., Nordin, U., Söderström, B. & Gustafsson, L. (2009). Retention patches as potential refugia for bryophytes and lichens in managed forest landscapes. *Biol. Conserv. 142*, 1125–1133. https://doi.org/10.1016/j.biocon.2008.12.033

Kouki, J. (2013). Nuoret luonnonmetsät metsien hoidon ja suojelun mallina. Uusia mahdollisuuksia metsäluonnon suojeluun talousmetsissä. Luonnon Tutkija 1-2 (2013), 4–19.

Selonen, V.A.O. & Kotiaho, J. (2013). Buffer strips can pre-empt extinction debt in boreal streamside habitats. *BMC Biology 13(24)*. https://doi.org/10.1186/1472-6785-13-24

Vanha-Majamaa, I., Lilja, S., Ryömä, R., Kotiaho, J.S., Laaka-Lindberg, S., Lindberg, H., Puttonen, P., ... Kuuluvainen, T. (2007). Rehabilitating boreal forest structure and species composition in Finland through logging, dead wood creation and fire: the EVO experiment. *For. Ecol. Manag. 250*, 77–88. https://doi.org/10.1016/j.foreco.2007.03.012

9.3 A compilation of relevant literature for NBS in freshwater ecosystems

Aradóttir, Á. L., Petursdottir, T., Halldorsson, G., Svavarsdottir, K. & Arnalds, O. (2013). Drivers of Ecological Restoration: Lessons from a Century of Restoration in Iceland. *Ecology and Society, 18(4).* doi:10.5751/ES-05946-180433

Berninger, K., Koskiaho, J & Tattari, S. (2012). Constructed wetlands in Finnish agricultural environments: Balancing between effective water protection and multi-functionality. *Journal of Water and Land Development 17(1).* DOI:10.2478/v10025-012-0029-5

Braskerud, B. C. (2001). Sedimentation in Small Constructed Wetlands. Retention of Particles, Phosphorus and Nitrogen in Streams from Arable Watersheds. Doctor Scientiarum Theses 2001:10, Agricultural University of Norway. Retrieved from: https://www.researchgate.net/publication/344956378_Sedimentation_in_Small_Constructed_Wetlands_Retention_of_Particles_Phosphorus_and_Nitrogen_in_Streams_from_Arable_Watersheds

De La Haye, A., Devereux, C., & van Herk, S. (2021). *Peatlands Across Europe: Innovation & Inspiration. State of the Art & Guide to Next Steps.* Barcelona: Bax & Company. Retrieved from: https://www.decadeonrestoration.org/publications/peatlands-across-europe-innovation-and-inspiration

Ekologgruppen (2003a). *Dammar som reningsverk. Mätningar av näringsämnesreduktionen i nyanlagda dammar.* 1993–2002. Höje å projektet & Kävlingeå-projektet. Retrieved from: http://xn--hje-wla6f.se/rapporter/Dammar_som_reningsverk_2003.pdf

Ekologgruppen (2003b). *Biologi och vattenkemi i nya dammar. Undersökningar 2000–2002, slutrapport.* Biologi och vattenkemi i nya dammar - PDF Free Download (docplayer.se)

Ekologgruppen (2003c). *Segeå-projektet. Uppföljning av 50 dammar. Våtmarker och hydrologiska effekter.* Commissioned by Segeåns Vattendragsförbund October 2003 (revised april 2005). Retrieved from: https://segea.se/wp-content/uploads/2020/12/E1_Segea_50_dammar_2003.pdf

Ekologgruppen (2007). *Segeå-projektet. Etapp 2 – slutrapport.* Commissioned by Segeåns Vattendragsförbund, January 2007. Retrieved from: Microsoft Word - Slutrapp_etappII_2006.doc (segea.se)

Frolking, S., Talbot, J., Jones, M. C., Treat, C. C., Kauffman, J. B., Tuittila, E.-S., & Roulet, N. (2011). Peatlands in the Earth's 21st century climate system. *Environmental Reviews, 19(NA)*, 371–396. https://doi.org/10.1139/a11-014

Halldórsson, G., L., Aradóttir, Á., Maria Fosaa, A., Hagen, D., Nilsson, C., Raulund-

Rasmussen, K., ... & Tolvanen, A. (2012). *ReNo. Restoration of damaged ecosystems in the Nordic countries.* TemaNord 2012:558. Copenhagen: Nordic Council of Ministers. Retrieved from: https://land.is/wp-content/uploads/2018/01/ReNo.pdf

Hoffmann, C. C., Zak, D., Kronvang, B., Kjaergaard, C., Carstensen, M. V., & Audet, J. (2020). An overview of nutrient transport mitigation measures for improvement of water quality in Denmark. Ecological Engineering, 155, 105863. https://doi.org/10.1016/j.ecoleng.2020.105863

Hristov, I. (2004). *Wetland Types and Classifications.* Central European University. Retrieved from: http://www.personal.ceu.hu/students/03/nature_conservation/wwddetail/Types_classif.html

Hutchins, M. G., Fletcher, D., Hagen-Zanker, A., Jia, H., Jones, L., Li, H., ... Yu, S. (2021). Why scale is vital to plan optimal nature-based solutions for resilient cities. E*nvironmental Research Letters, 16(4)*, 044008.

IUCN - The International Union for Conservation of Nature (2020). *Global Standard for Nature-Based Solutions. A User-Friendly Framework for the Verification, Design and Scaling up of NbS.* First edition. Gland, Switzerland: IUCN. Retrieved from: https://portals.iucn.org/library/sites/library/files/documents/2020-020-En.pdf

Johannesson, K.M., Kynkäänniemi, P., Ulén, B., Weisner, S.E.B. & Tonderski, K. S (2015). Phosphorus and particle retention in constructed wetlands—A catchment comparison. *Ecological Engineering 80 20–31.* http://dx.doi.org/10.1016/j.ecoleng.2014.08.014

Koskiaho, J., Ekholm, P., Räty, M.,Riihimäki, J., Puustinen, M. (2003). Retaining agricultural nutrients in constructed wetlands - Experiences under boreal conditions. *Ecological Engineering 20, 89(103).* doi:10.1016/S0925-8574(03)00006-5

Strand, J. A. & Weisner, S. E. B. (2013). Effects of wetland construction on nitrogen transport and species richness in the agricultural landscape—Experiences from Sweden; *Ecological Engineering 56 14–25.* https://doi.org/10.1016/j.ecoleng.2012.12.087

Svensson, J. M., Strand, J. A., Sahlén, G., & Weisner, S. E. B. (2004). *Rikare mångfald och mindre kväve: Utvärdering av våtmarker skapade med stöd av lokala investeringsprogram och landsbygdsutvecklingsstöd.* Retrieved from: http://urn.kb.se/resolve?urn=urn:nbn:se:hh:diva-1856

Syversen, N. (2005). Effect and design of buffer zones in the Nordic climate: The influence of width, amount of surface runoff, seasonal variation and vegetation type on retention efficiency for nutrient and particle runoff. *Ecological Engineering 24,* 483–490. https://doi.org/10.1016/j.ecoleng.2005.01.016

Thiere, G., Milenkovski, S., Lindgren, P.-E., Sahlén, G., Berglund, O., & Weisner, S. E. B. (2009). Wetland creation in agricultural landscapes: Biodiversity benefits on local and regional scales. *Biological Conservation, 142(5),* 964–973.

Tonderski, K.S., Arheimer, B. & Pers, C.B. (2005). Modeling the Impact of Potential Wetlands on Phosphorus Retention in a Swedish Catchment. A Journal of the Human Environment, 34(7), 544–551. http://dx.doi.org/10.1579/0044-7447-34.7.544

Uusi-Kämppä, J., Braskerud, B., Jansson, H., Syversen, N & Uusitalo, R. J. (2000). Buffer Zones and Constructed Wetlands as Filters for Agricultural Phosphorus, *Journal of Environmental Quality, 29,* 151–158. https://doi.org/10.2134/jeq2000.00472425002900010019x

Vikman, A., Sarkkola, S., Koivusalo, H., Sallantaus, T., Laine, J., Silvan, N., Nousiainen, H., Nieminen, M. (2010). Nitrogen retention by peatland buffer areas at six forested catchments in southern and central Finland. *Hydrobiologia 641,* 171–183; https://doi.org/10.1007/s10750-009-0079-0

Zak, D., Kronvang, B., Carstensen, M., Hoffmann, C. C., Kjeldgaard, A., Larsen, S. E., Audet, J., … Jensen, H. S. (2018). Nitrogen and Phosphorus Removal from Agricultural Runoff in Integrated Buffer Zones. *Environmental Science & Technology, 52(11)*, 6508–6517. https://doi.org/10.1021/acs.est.8b01036

About this publication

Working with Nature-Based Solutions

Synthesis and mapping of status in the Nordics

Leonard Sandin, Isabel Seifert-Dähnn, Ingvild Skumlien Furuseth, Annette Baattrup-Pedersen, Dominik Zak, Johanna Alkan Olsson, Helena Hanson, Samaneh Sadat Nickayin, Maria Wilke, Matti Koivula, Marika Rastas, Caroline Enge, Kristina Øie Kvile, Lisa Lorentzi Wall, Carl Christian Hoffmann, and Rúna Þrastardóttir

ISBN 978-92-893-7461-3 (PDF)
ISBN 978-92-893-7462-0 (ONLINE)
http://dx.doi.org/10.6027/temanord2022-562

TemaNord 2022:562
ISSN 0908-6692

Cover photo: Benjamin Kupilas, NIVA: *Hovinbekken – a reopened stream in Oslo.*

Published: 6/1/2023

Disclaimer

This publication was funded by the Nordic Council of Ministers. However, the content does not necessarily reflect the Nordic Council of Ministers' views, opinions, attitudes or recommendations.

Rights and permissions

Nordic co-operation

Nordic co-operation is one of the world's most extensive forms of regional collaboration, involving Denmark, Finland, Iceland, Norway, Sweden, and the Faroe Islands, Greenland and Åland.

Nordic co-operation has firm traditions in politics, economics and culture and plays an important role in European and international forums. The Nordic community strives for a strong Nordic Region in a strong Europe.

Nordic co-operation promotes regional interests and values in a global world. The values shared by the Nordic countries help make the region one of the most innovative and competitive in the world.

The Nordic Council of Ministers
Nordens Hus
Ved Stranden 18
DK-1061 Copenhagen
pub@norden.org

Read more Nordic publications on www.norden.org/publications