NATUR VÅRDS VERKET
SWEDISH ENVIRONMENTAL PROTECTION AGENCY

Nature-based solutions

A tool for climate adaptation and other societal challenges

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Foreword

The world is facing a double crisis – a changing climate and the accelerating loss of biodiversity. These two crises are closely interrelated and affect each other. We cannot solve the climate crisis without managing biodiversity loss, and we cannot halt that loss without addressing the climate crisis.

Nature-based solutions are multifunctional, cost-effective actions for addressing various societal challenges by protecting, developing or creating ecosystems while promoting biodiversity and human well-being. They have emerged as cost-effective solutions that both solve the problem in focus while providing other benefits in the process. Because nature-based solutions generate multiple gains, they are one of the most vital tools we possess for simultaneously addressing climate challenges and biodiversity loss together with other societal challenges.

The purpose of this report is to disseminate knowledge and information about nature-based solutions and to offer guidance on how they can be planned and implemented to meet the challenges that a changing climate brings while creating added value. The report also aims to provide inspiration, with many Swedish examples of such solutions that have already been implemented. It is the Swedish Environmental Protection Agency's hope that this guidance and all the examples will shed light on questions about what nature-based solutions are and inspire more of these solutions to be chosen, especially in climate adaptation efforts.

The guidance on nature-based solutions is the first Swedish national roadmap in this area. The work was initiated by the Swedish Environmental Protection Agency and has been run by Anki Weibull and Timo Persson together with many of our staff, who have provided their expertise and perspectives throughout the process from idea to the final document you are now reading. A selection of the experts involved include ecologists, land use planners and economists. In addition we received valuable input and ideas from the project's reference group, consisting of the National Board of Housing, Building and Planning, the Swedish Geotechnical Institute SGI, the Swedish Meteorological and Hydrological Institute SMHI, the Swedish Board of Agriculture, the Swedish Civil Contingencies Agency and the Swedish Forest Agency, in addition to several county administrative boards and municipalities. Thank you for your contributions.

This report is a translation of a report written in Swedish (report no 7016 Naturbaserade lösningar – ett verktyg för klimatanpassning och andra samhällsutmaningar) and was tranlated by Lisa Del Papa, Språkkonsulterna.

Stockholm, March 2021

SWEDISH ENVIRONMENTAL PROTECTION AGENCY

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1

Introduction

Nature-based solutions are multifunctional, cost-effective actions for addressing various societal challenges by protecting, developing or creating ecosystems while promoting biodiversity and human well-being. The main objectives of nature-based solutions are to promote a sustainable development of society, strengthen biodiversity and ecosystem services, create multifunctionality, and increase resilience while reducing vulnerability.

Climate change has, and will have even more, significant consequences for social structures as well as natural environments. The negative effects of a changing climate, such as heat waves, droughts, cloudbursts, flooding, landslides and erosion, forest fires and rising sea levels, pose a major challenge for society, which is largely adapted to the prevailing climate. This places great demands on actions for securing a robust development of society that responds to the effects of a changing climate. As climate change becomes more and more apparent, the degradation of ecosystems and loss of biodiversity are undermining nature's own ability to curb climate change and reduce the negative effects of extreme weather. This, in turn, worsens climate change, which is currently viewed as the third largest global driver of biodiversity loss.[1] This combined crisis involving the climate and biodiversity therefore risks jeopardising the natural systems and ecosystem services that our entire society depends on.

More recently, awareness and knowledge of the need and added value of managing these crises have both increased. Nature-based solutions, which are capable of simultaneously addressing both the climate challenge and biodiversity loss, have thus been identified as an important solution by both the UN Panel on Biological Diversity and Ecosystem Services (IPBES)[2] and the UN Intergovernmental Panel on Climate Change (IPCC).[3]

Fundamentally, nature-based solutions are about harnessing nature's own ability to manage various societal challenges through measures that leverage and enhance biodiversity and ecosystem services. For example, the construction of wetlands and restoration of watercourses help us to delay and regulate high water flows in the landscape; parks and urban greenery help us to lower high temperatures and manage stormwater; restoring coastal ecosystems helps us to reduce erosion and flooding from rising sea levels; nature-based farming practices in agriculture and forestry promote resilient, long-term sustainable production. Studies also show that nature-based solutions have the potential to provide about 30 % of the cost-effective mitigation that is needed by 2030 to stabilise global warming to below 2 °C.[4] At the same time, nature-based solutions are capable of addressing numerous other challenges, such as eutrophication and air or noise pollution, and of acting as

[1] Global Assessment Report on Biodiversity and Ecosystem Services 1 IPBES
[2] Global Assessment Report on Biodiversity and Ecosystem Services 1 IPBES
[3] Global Warming of 1.5 °C – ipcc.ch
[4] Griscom et al. 2017.

an enabler for recreation, health and human well-being. In addition, nature-based solutions help to promote biodiversity, of course, so that we can continue to benefit from the ecosystem services that nature provides us with.

Nature-based solutions are therefore a powerful tool both for curbing climate change and for managing the negative effects of a changing climate – while providing us with several other societal benefits in the process.

Our societies are at a pivotal time now, where we understand that traditional technical solutions (so-called grey solutions) that used to be considered the best option for addressing climate-related challenges are not enough. In several cases, a technical solution can be both necessary and well-functioning. But if we blindly choose a grey solution without much reflection, we miss the chance to solve several major societal problems with a single solution, something that nature-based solutions can help us do. Nature-based solutions can play a key role in addressing the interlinking crises around climate and biodiversity, while contributing to transformative and sustainable development.

A guide for readers

This report describes what nature-based solutions are, presents several cases from different types of nature and provides guidance on how to use nature-based solutions. The guidance is comprehensive so that it can function regardless of the type of nature, environment or sector that is in focus. It offers a general approach, stressing the importance of engaging relevant stakeholders and of choosing and designing measures that do not harm the environment but instead strengthen biodiversity and the production of ecosystem services.

The starting point for this guidance is climate adaptation and the reduction of disaster risk in a Swedish context, but the approach presented works even if other challenges are the starting point for the efforts.

The guidance for nature-based solutions is divided into six steps: Identify climate-related risks and vulnerabilities, Identify the socio-environmental context, List possible solutions, Prioritise a solution, Implement the solution, and, finally, Follow up and evaluate it. At the heading level there a clear common thread throughout the process. In detail, however, the different steps of the process will be intertwined, and some analyses presented in later stages might need to be carried out in earlier steps, at a more basic level. For example, the identification of risks in step 1 is linked to the follow-up and evaluation step. Another example involves measures that require external funding or permits under the Environmental Code, which can be a time-consuming process. If such a need exits, it is wise to clarify this early in the process (for example, in step 3) even if the application or permitting procedure itself does not begin until an action has been chosen (meaning step 5).

The six steps should therefore not be considered as static steps that are strictly dependent on a chronological order of implementation. Rather, they offer guidance on an iterative and dynamic approach that allows for efforts to flow back and forth between the steps.

Chapter 2 sets out the international and national commitments related to nature-based solutions and defines, describes and provides examples. Chapter 3 presents a step-by-step guide to analysing needs and conditions and for planning, implementing and following up an NbS action. Chapter 4 presents different nature-based solutions in various types of landscapes. These cases are intended to serve as a bank of ideas and inspiration. In-depth information on various international definitions of nature-based solutions and of other related concepts, as well as a description of ongoing national efforts, are presented in Appendix 1.

2

Nature-based solutions

Nature-based solutions are multifunctional, cost-effective actions for addressing various societal challenges by protecting, developing or creating ecosystems while promoting biodiversity and human well-being. This strengthens the ability of ecosystems to provide us with the necessary ecosystem services[5] which in turn help us to solve these challenges.

The starting point for a nature-based solution can be one or more different societal challenges. Added value is created by choosing and designing a solution that provides several co-benefits and thus helps to solve several problems at once. If the starting point is to limit the impact of climate change on communities and infrastructure by regulating the amount of water or elevated temperatures in cities, the added value of an appropriately designed nature-based solution might be enhanced biodiversity, reduced air pollution, and more spaces for recreation and social well-being.[6] Nature-based solutions are characterised by their multifunctionality, meaning that they can produce co-benefits at the same time, whether environmental, social or economic.

Well-functioning ecosystems provide us with many ecosystem services. But an ecosystem affected by something like intensive land use has often been depleted in a way that decreases the biodiversity of the system. Ecosystems with low biodiversity are more sensitive to disturbances and changes, which means that they have low resilience. Resilience is the capacity of a system, such as a forest, a city or an economy, to manage change and continue to evolve. It thus involves both an ability to bounce back and to adapt, transforming shocks and disturbances like climate change into opportunities for renewal and innovative thinking.[7]

Nature-based solutions show the potential to provide us with a diversity of benefits while enhancing biodiversity and thus helping to create communities that are more resilient and adaptable. They are sometimes referred to as “no-regret solutions” because they deliver multiple positive effects. So, even if climate change turns out to be less extensive than models predict, nature-based solutions will give us other gains that benefit our welfare and resilience.[8]

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[5] Ecosystemtjänster, naturvardsverket.se

[6] The solution is in nature, Future Brief 24, 2021, europa.eu

[7] Stockholm University, Stockholm Resilience Centre. Vad är resiliens? stockholmresilience.org

[8] Eco_bfn – Nature-based approaches for climate change mitigation and adaptation, 2014, ecologic.eu

Definition

Nature-based solutions (NbS) are different actions that leverage ecosystems' own abilities in order to meet the challenges we face. The idea of letting nature do the work has come up in different forums and contexts, so there are several slightly different definitions in circulation. What they have in common is that in one way or another, they take the role of ecosystems as their point of departure in solving various challenges in order to bolster resilience and human well-being. Regardless of the definition, the solutions are designed based on the challenge at hand by strengthening ecosystem services. This can be done by preserving, restoring or creating ecosystems and by managing and using them sustainably. You can read more about the different definitions of nature-based solutions in the appendix "Nature-based solutions – a closer look".

The Swedish Environmental Protection Agency has chosen to interpret and define nature-based solutions as follows:

> Nature-based solutions are multifunctional, cost-effective actions for addressing various societal challenges by protecting, developing or creating ecosystems while promoting biodiversity and human well-being.

In practice, nature-based solutions can vary to a great extent.

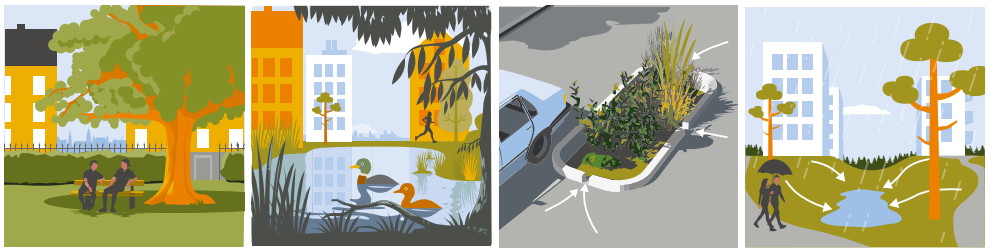
Broadly speaking, they can be divided into three different types[9] including protection, sustainable management, and creation and regeneration of all or part of an ecosystem:

1. **Conservation and restoration of existing ecosystems**. Here, no or minimal measures are present in the existing ecosystem and the focus is to ensure and benefit from the ecosystem services provided by the existing ecosystem. This can involve establishing or preserving protected areas.
2. **Management and sustainable use of ecosystems**. The focus here is on adapting management and actions to promote ecosystem services, sustainability and multifunctionality in these ecosystems and landscapes. This can involve farming practices in agriculture, forestry or fishing.
3. **Regeneration of degraded ecosystems or creation of new ones**. For example, this can involve restoring previously existing wetlands. During restoration, the effort can be innovative and encompass the interplay of technology and biology, such as installing rain gardens for stormwater management in an urban environment.

[9] ThinkNature, NatureBased Solutions Handbook 2019, thinknature.eu

Figure 1 illustrates examples of nature-based solutions for climate adaptation in different types of landscapes.

Figure 1. Examples of nature-based solutions in different types of landscapes.



In urban environments: Trees and park environments help regulate temperatures and offer a way to cool off. With the right design and location, greenery can also promote better health through noise reduction and the reduced dispersion of airborne particles, and it can provide areas for recreation while becoming a vital biodiversity feature and creating beauty value in the urban environment. Wetlands, rain gardens and infiltration basins can both detain and regulate peak flows during torrential rains and help equalise water supply during dry spells. They also improve water quality through infiltration and phytoremediation, whereby plants help to remove harmful substances from soil and watercourses, reducing the pollutant load on receiving waters.

In forest landscapes: Area protection can be established to maintain existing ecosystem services; mixed forests can be promoted instead of monocultures to better withstand insect pressure and storms; continuous cover forestry can be applied to reduce downstream flooding; and natural regeneration and site-adapted forestry can be introduced to increase resilience against disturbances such as storms. The conservation, restoration and construction of wetlands detains and stores water in the landscape while promoting the conditions for biodiversity. Wetlands are habitats that can be particularly vulnerable in a changing climate and can provide fire protection and, in some situations, reduce the risk of flooding. Rewetting peatlands reduces greenhouse gas emissions.

In agricultural landscapes, a variety of crops can create resilience and secure parts of the harvest if exposed to intense drought or heavy rainfall. No-till agriculture slows the path of water through the landscape; the installation of shaded groves and vegetation that abuts farmland can reduce damage from wind, among other stresses, and offer shade for livestock when temperatures are high. The construction, preservation and restoration of wetlands in the agricultural landscape can reduce the risk of water scarcity during droughts and can protect against flooding.

In coastal environments, dune environments can help protect against erosion and flooding. Coastal vegetation can bind the sand together so that it does not erode. Natural coastal ecosystems can be re-created through the removal of invasive non-native species, promoting natural coastal dynamics and dune formation processes. Eelgrass beds can help attenuate wave energy and reduce erosion. By removing impenetrable barriers or freeing up space on land, protected ecosystems can be allowed to migrate up along the shore when sea levels rise.

Why we should pursue nature-based solutions

The world is facing a double crisis – a changing climate and the accelerating loss of biodiversity. These two crises are closely interrelated and affect each other, both directly and indirectly. We cannot solve the climate crisis without managing biodiversity loss, and we cannot halt that loss without addressing the climate crisis. Nature-based solutions are one of the most crucial tools we have at our disposal for managing this twofold challenge. This is why we should step up the use of nature-based solutions in our efforts to limit climate impact and to mitigate climate change. Our communities are at a pivotal time now, where nature-based solutions can play a key role in addressing the combined climate and biodiversity crisis while contributing to transformative, sustainable development.

Goals

Nature-based solutions can, in an integrated way, address the dual challenges of climate change and ongoing biodiversity loss. A nature-based solution is best designed for solving the societal challenge in focus, while meeting the overarching goal of reducing vulnerability and increasing resilience throughout society in order to achieve robust ecosystems and improve human well-being. In other words, there are several different goals when pursuing the use of nature-based solutions. For solutions geared towards climate adaptation, efforts can be divided into the following subgroups (developed from the EU project ThinkNature[10] and the objectives of the Convention on Biological Diversity (CBD)[11]; see Figure 2):

- **Promote sustainable social development based on interaction and participation.** Much of the world's population lives in urban environments and faces major challenges, such as air pollution and a lack of access to clean water and other natural resources, which contribute to a decline in well-being.
- **Strengthen biodiversity and ecosystem services**. A host of ecosystems have been severely damaged through human activity as well as land and water overuse, in turn impacting the capability to deliver ecosystem services.
- **Create multifunctional solutions and co-benefits (climate adaptation and other benefits)**. Take advantage of the contribution that one adaptation measure makes to producing other benefits, such as reducing climate-driven emissions.
- **Increased resilience and adaptability, and reduced vulnerability**. There are a variety of climate-related events that can result in huge losses of both natural and societal resources without preventive measures.

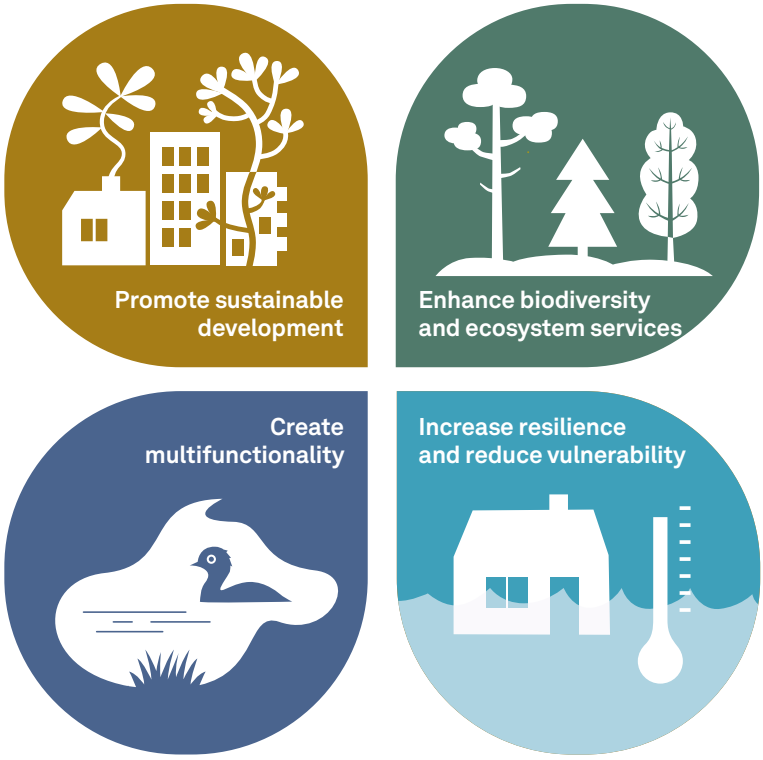
When setting goals, it is important to remember that city and country are interrelated, which is why this categorisation of goals includes both. It is difficult to achieve biodiversity goals, reduce climate emissions and boost resilience without

[10] ThinkNature, NatureBased Solutions Handbook 2019, thinknature.eu

[11] Voluntary guidelines for the design and effective implementation of EbA to climate change adaptation and disaster risk reduction and supplementary information, cbd.int.

widening one's perspective and viewing the challenges from a landscape perspective[12] or a broader context.[13] It is also essential for individual nature-based solutions to be part of a comprehensive strategy for adaptation and risk management supported by multiple sectors and levels of society.

Figure 2. Goals for pursuing nature-based solutions in climate adaptation can be divided into four categories.



[12] A landscape perspective means taking the context into account in addition to the object (or problem) level, to include environmental aspects that are not limited to the individual object or problem.

[13] Arbetssätt för biologisk mångfald och andra värden i ett landskapsperspektiv, Swedish Environmental Protection Agency, naturvardsverket.se

Safeguards and criteria

To achieve the different goals when applying nature-based solutions, it is important to ensure that all three aspects of the sustainability paradigm – economic, environmental and social – are taken into account. Like the different definitions of nature-based solutions, there are several sets of safeguards or criteria for ensuring that all sustainability aspects are included in the design and implementation of nature-based solutions. Table 1 presents the aspects to consider during the planning, implementation and follow-up of nature-based solutions. These criteria are a synthesis of the safeguards that CBD highlights in its guidance and the criteria highlighted by the IUCN in its global standard for nature-based solutions.[14] As you follow the steps in the guidance, these safeguards are included as a natural part of the entire process.

Table 1. Safeguards, or criteria, to be included in the planning, implementation and follow-up of nature-based solutions to ensure that environmental, economic and social aspects are taken into account.

Addressing societal challenges together	Prioritise, together with stakeholders, which challenge is most important to address.
Design a solution depending on the scale	Scale refers not only to geographical scale, but to the scale among people, the economy and ecosystems and synergies with other sectors. Use an environmental impact assessment[15] at the early stage of the project.
Promote biodiversity	Seek solutions that promote biodiversity and enhance ecosystem function. Avoid biodiversity loss or introducing invasive non-native species.
Economic sustainability	Clarify the direct and indirect gains and costs. Long-term gains must be balanced against short-term costs. Strive for energy efficiency and sustainable material use, avoiding increased climate emissions.
Ensure transparency and participation, respect rights	Ensure that everyone concerned gets the chance to participate throughout the process. This applies to everyone from landowners and local residents, indigenous peoples and local communities to associations, youth and the elderly, taking gender equality perspective. Participation helps to prioritise measures and contributes to the long-term sustainability of a measure. Respect the rights of the Sami people.
Avoid misalignment	Avoid moving risks from one place to another, making a negative impact on both people and the environment. This entails weighing goals and interests against each other on site, something preferably done using participatory processes. It is important not to compromise the long-term integrity of the ecosystems, as loss of ecosystems can be irreversible.
Use adaptive management, with open and accessible information	By following up on the effects of a measure, it can be adapted as needed. Information on both the implementation and follow-up of the action should be available to stakeholders.
Anchor across sectors with plans and policies	Nature-based solutions provide solutions for a variety of sectors. One solution's added value can impact a completely different sector from the focus sector.

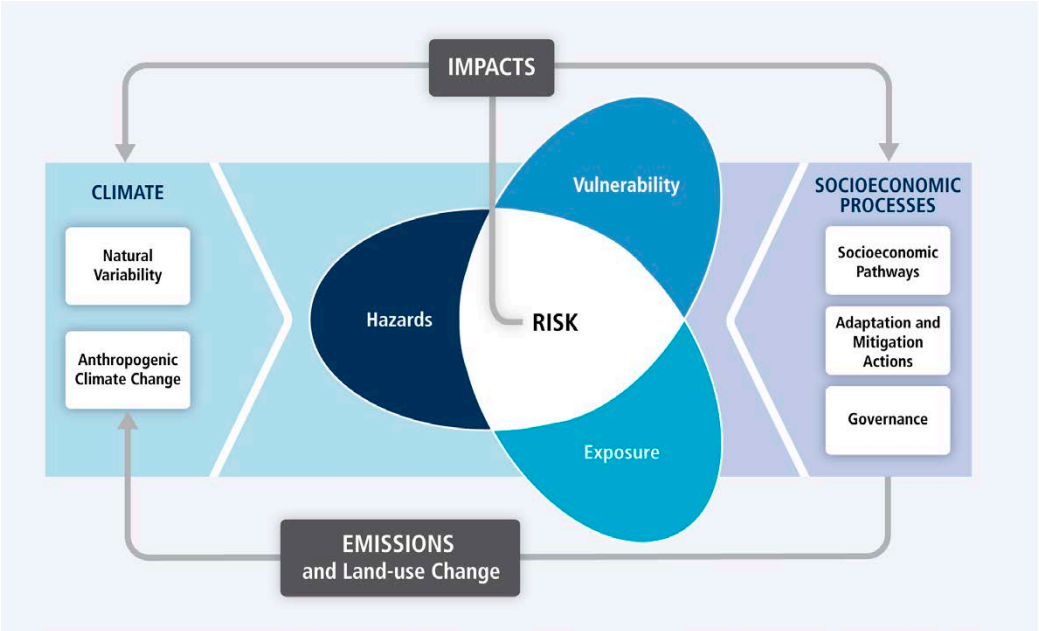
[14] IUCN Global Standard for Naturebased Solutions 2020020En.pdf (iucn.org)

[15] Miljökonsekvensbeskrivningen i den specifika miljöbedömningen – Naturvårdsverket (naturvardsverket.se)

Humans, nature and the climate

Humans have an impact on the climate, and climate change creates threats and risks for us and our communities.[16] Climate change also has an impact on biodiversity and ecosystem services that underpin our well-being, thereby driving and creating additional risks. To find sustainable solutions to the challenges we face, we must consider the complex relationship among the environmental, social and economic dimensions. The UN Intergovernmental Panel on Climate Change (IPCC) has illustrated the relationship among the risks of climate-related impacts resulting from the interaction between climate-related hazards (including dangerous events and trends) and the vulnerability and exposure of human and natural systems. The IPCC underscores that climate change, as well as changes in socio-economic processes including adaptation measures and emission limitations, are factors that affect hazards, exposure and vulnerability (see Figure 3).

Figure 3. How great the risk of climate-related effects is depends on several interacting factors: climate-related events and the vulnerability of both human and natural systems. Changes in both climatic factors (at left) and socio-environmental processes (at right) drive the risk of dangerous events and vulnerability. Source: Intergovernmental Panel on Climate Change, Climate Change 2014: Impacts, Adaptation and Vulnerability, 2014.[17]



In parallel, human activity, especially land use change, has a devastating impact on biodiversity. In its global assessment, the IPBES finds that land use change has been the main driver of reduced terrestrial biodiversity, but the importance of climate change as a driving force is growing, not least through interaction with other drivers like land use.[18] Land use itself also has a major impact on the climate, and climate change is increasingly affecting biodiversity and ecosystem services.[19]

[16] https://www.smhi.se/nyhetsarkiv/darforbehoverviklimatanpassanykortfilmforklarar1.169078
[17] https://www.ipcc.ch/site/assets/uploads/2018/02/ar5_wgII_spm_en.pdf
[18] Global Assessment Report on Biodiversity and Ecosystem Services, IPBES 2019
[19] Klimatförändringar och biologisk mångfald – Slutsatser från IPCC och IPBES i ett svenskt perspektiv, smhi.se

Sustainable land use practices will play a crucial role in the future health of our ecosystems, so individual nature-based solutions alone will not suffice for solving specific societal problems.

International and national commitments

Several international conventions, agreements and partnerships have recently indicated that ecosystem vulnerability is linked to social vulnerability and society's vulnerability to climate change. This insight rests on an evidence base from both the UN's knowledge platform for climate change (IPCC) and for biodiversity (IPBES). The scientific community underscores that nature-based solutions play a prominent role in tackling the challenges of climate change and biodiversity in an integrated way.

The evidence base for the benefits of nature-based solutions is clear and strong. There are a number of political processes with associated goals and policies that lay the foundation for work on nature-based solutions:

A manifesto for nature-based solutions. During the UN's climate summit in New York in September 2019, a manifesto for nature-based solutions was signed by many countries including Sweden. The manifesto states that nature-based solutions can be used to "unlock the full potential of nature for climate action".[20] This is why we should step up the use of nature-based solutions in our efforts to limit climate impact and to mitigate climate change. The manifesto identifies four priority areas:

1. Mainstream nature-based solutions in plans and programs
2. Enhance cooperation
3. Shift governance and financing
4. Scale up nature-based solutions for climate resilience, mitigation and adaptation.

Leaders' pledge for nature. In September 2020, the UN invited political leaders to its Summit on Biodiversity. At the summit, 84 countries including Sweden signed a pledge to reverse the trend of global biodiversity loss by 2030. In the pledge, countries promise to scale up nature-based solutions and allocate sufficient resources for them to ensure human well-being and to protect the planet.[21]

The 2030 Agenda. Several of the UN's sustainable development goals (SDGs) adopted by the UN General Assembly aim directly or indirectly at enhancing the use of ecosystems and biodiversity as tools for addressing various societal challenges.[22] Some clear examples include SDG 13 on climate action, SDG 11 on sustainable cities and communities, SDG 15 on life on land, SDG 14 on life below water, SDG 3 on health and well-being, and SDG 6 on clean water and sanitation.[23]

[20] NatureBased Solutions for Climate. UNEP UN Environment Programme
[21] https://www.un.org/pga/75/unitednationssummitonbiodiversity
[22] https://sdgs.un.org/
[23] ThinkNature, NatureBased Solutions Handbook 2019, thinknature.eu

The Convention on Biological Diversity (CBD) highlights the potential of nature-based solutions in relation to climate change specifically,[24] and more broadly in relation to the achievement of other biodiversity goals and the UN's SDGs.

The EU Green Deal 2020, with a new biodiversity strategy for 2030. Within the framework of the new European Commission, the so-called Green Deal has been presented. It contains several components, including a biodiversity strategy leading up to 2030. The Green Deal states that nature regulates the climate, and that nature-based solutions will be crucial for emission reductions and climate adaptation. Furthermore, it underscores the importance of halting biodiversity loss and of green ecosystems in cities by systematically promoting green infrastructure and nature-based solutions in urban planning. In general, a particular focus will be placed on incentivising and removing barriers to nature-based solutions.[25]

The Sendai Framework for Disaster Reduction (SFDRR) in its global goals highlights the importance of prioritising efforts to strengthen ecosystem-based measures in order to build the resilience of communities and reduce risks resulting from natural disasters.

According to the SFDRR, the role of ecosystems and measures based on nature-based approaches must be given greater scope in plans to reduce risks resulting from natural disasters.[26]

The UN Framework Convention on Climate Change (UNFCCC). The Paris Agreement highlights the need for adaptation in order to create robust communities. Using nature-based solutions becomes a vital tool as sustainable use and intact ecosystems are identified as priority target areas.[27]

The Global Commission on Adaptation[28] identifies nature-based solutions as one of eight focus areas for strengthening adaptation efforts.[29]

Climate change adaptation in the EU. The EU's new climate adaptation strategy lays the foundation for managing the adverse effects of a changing climate. The strategy sheds light on the ever-growing economic losses from climate-related extreme events in the EU. Such losses already total close to 12 billion euros annually, and with a global temperature rise of 3 degrees this figure is expected to be at least 170 billion euros annually. The need to scale up adaptation efforts is underscored, and nature-based solutions highlighted as a vital tool for addressing challenges both in terms of biodiversity loss and climate change.[30]

[24] https://www.cbd.int/climate/intro.shtml
[25] Naturebased solutions. European Commission, europa.eu
[26] Sendai Framework for Disaster Risk Reduction 20152030, UNDRR
[27] The Paris Agreement, UNFCCC
[28] Home – Global Center on Adaptation, gca.org
[29] Infrastructure and NbS – Global Center on Adaptation, gca.org
[30] EU Adaptation Strategy, europa.eu

Environmental quality objectives. Nature-based solutions help to meet several of Sweden's 16 environmental quality objectives. Clear examples include Reduced Climate Impact, Thriving Wetlands, Sustainable Forests, A Good Built Environment, A Balanced Marine Environment, Flourishing Coastal Areas and Archipelagos, Flourishing Lakes and Streams, Good-Quality Groundwater, Zero Eutrophication, A Magnificent Mountain Landscape, and A Rich Diversity of Plant and Animal Life.

The starting point of the work on nature-based solutions – enhancing, maintaining and restoring ecosystems in the long term and the significance it has for other goals like public health and recreation – is also directly related to meeting the generational goal.[31]

The government appreciates the EU's development of a new biodiversity strategy, which has brought a welcome clarity on the synergies between climate and biodiversity and the cost-effectiveness that nature-based solutions can bring.[32]

The national strategy for climate adaptation. Sweden's national strategy for climate adaptation highlights the pivotal role nature-based solutions can play in both preserving and sustainably using biodiversity and ecosystem services, and in mitigating climate change impact.[33]

Ordinance (2018:1428) on climate adaptation efforts by public authorities. The government authorities must conduct climate and vulnerability analyses for their respective remits and find solutions to achieve the national goal of adaptation to a changing climate.[34] This means developing a sustainable and robust society for the long term that proactively addresses climate change by reducing vulnerabilities and leveraging opportunities. Here, nature-based solutions can serve as a vital tool in climate adaptation efforts.
The Climate Act (2017:720) requires the government to carry out climate policy efforts that help to protect ecosystems, as well as current and future generations, against the harmful effects of climate change.35 While this work should naturally focus on reducing greenhouse gas emissions, it should simultaneously strive to preserve and create functions in the environment that counteract climate change and its harmful effects. The efforts should be grounded in science.

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[31] Sweden's environmental objectives, sverigesmiljomal.se
[32] EU's biodiversity strategy for 2030, explanatory memorandum 43 2019/20, riksdagen.se
[33] Govt. Bill 2017/18:163: National strategy for climate adaptation, riskdagen.se
[34] Ordinance (2018:1428) on climate adaptation efforts by public authorities. Swedish Code of Statutes 2018:1428, Riksdag
[35] Climate Act (2017:720) Swedish Code of Statutes 2017:720, Riksdag

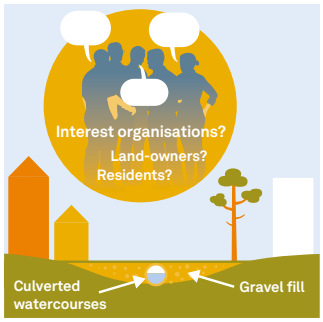
3

Guidance

This chapter describes six steps that support the broad implementation of sustainable solutions and, in particular, nature-based solutions, from problem formulation and planning through to implementation and follow-up. Sometimes a nature-based solution can be the optimal solution for addressing the challenge, while in other cases the answer can be found in a combination of nature-based and grey solutions, or for that matter a completely grey solution. Although the guidance aims to stimulate more multifunctional and cost-effective nature-based solutions, the approach ensures that all potential solutions, whether green or grey or a combination, are listed and evaluated in order to facilitate a sustainable choice of solution. The steps are based on a guide developed by the Convention on Biological Diversity (CBD) in 2018 and adapted for a Swedish context. The guidance provided during each step is designed to suit different challenges for various sectors, areas or landscapes.

The various steps in this guidance should be viewed as a supportive and inspiring implementation regime for NbS actions. This does not mean that every step must be followed to the letter; each site and responsible operator has its own set of circumstances that will influence how and in what order the work should be carried out in the best possible way. The steps are connected and overlapping, so they can function in parallel during different stages.

Step 1. Identify climate-related risks and challenges: Identify where there is a risk that arising climate-related challenges must be addressed.

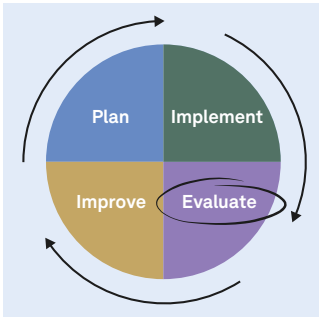


Step 2. Identify and understand the socio-environmental context: Establish an understanding of the conditions for pursuing nature-based solutions.

Step 3. List possible solutions: Identify the possible solutions that are suitable for addressing the challenge.

Step 4. Prioritise a solution: Analyse the consequences of potential solutions to enable prioritisation among options.

Step 5. Implement the solution: When you have chosen the ideal solution, implement it based on the goals, analyses and priorities made in previous steps.



Step 6. Follow-up and evaluate: Analyse and evaluate the outcome of the solution to ensure that the goals have been achieved or see if they should be adjusted.

The guidance aims to build knowledge about nature-based solutions and reveal working practices that can stimulate more solutions. The party overseeing these efforts can be anyone from a municipality to an individual landowner. Two key approaches that run through the guidance are participation and consideration. Participation means that the process should be open, transparent and involve the participation of local stakeholders, indigenous peoples, local communities, interest associations and other citizens. Understanding traditional local knowledge throughout the participatory process is important. Consideration mainly means to take biological diversity into account when designing solutions that improve diversity, as well as to consider how the solutions can avoid negatively impacting the climate goals or other environmental objectives.

Step 1. Identify climate-related risks and vulnerabilities

The first step aims to identify the risks posed by climate change in the focus area and to answer questions about where key public services are found or the areas with major environmental, social or cultural significance. Understanding this requires knowledge about ecological and social conditions and their links to the landscape, which step two aims to identify. The first and second steps in this guidance are therefore interdependent.

The goal of step 1 is to identify how the climate is changing and what climate-related risks can arise and to evaluate their possible impacts on ecosystems and society. Examples of the weather-related impacts of climate change can include the more frequent risk of droughts and heat waves which can lead to negative health impacts and water scarcity; torrential rains that lead to flooding, avalanches or landslides; sea level rises that increase the risk of coastal erosion; or decreased soil frost depth during the winter that increases the risk of trees falling during storm events.

In this step, a climate risk and vulnerability assessment is performed to identify the main risks a changing climate can entail within the geographical area and the activity. A risk and vulnerability assessment aims to systematically identify various undesirable events, assess how likely these events will occur, assess the immediate negative impacts, analyse the vulnerabilities of the activity, and assess the ability to manage different stresses.[36] How vulnerable is the community or ecosystem to the negative effects of climate change in the area or landscape being studied? What risks does this entail? In this context, risk is the product of the probability of an adverse event occurring and the weight of its consequences.

Sweden's municipalities are required by law to produce a risk and vulnerability assessment. The Act on Municipal and County Council Measures Prior to and During Extraordinary Events In Peacetime and During Periods of Heightened Alert (2006:544) stipulates that municipalities and regions must analyse which extraordinary events in peacetime can occur in the municipality and county council, respectively, and how these events can affect their own operations. The results of this analysis must be evaluated and compiled in a risk and vulnerability assessment.[37]

Several methods for analysis and assessment are available, and the method chosen should be based on the conditions in the project. However, the risk assessment is usually performed in the following three steps covering climatological, environmental and social factors:

1. Identify and describe the risks.
2. Analyse the probability and consequences.
   (What could happen? How likely is it? What are the consequences?)
3. Assess the risk.

[36] Guidance for government agencies' 2020 risk and vulnerability assessment report: Based on the Swedish Civil Contingencies Agency's regulations on government agencies' risk and vulnerability assessments (MSBFS 2016:7)
[37] Risk och sårbarhetsanalyser, msb.se

1 IDENTIFY AND DESCRIBE THE RISKS

The climate shifts continuously over time, so the risks and vulnerabilities that exist today might change and create new challenges. This is true, for example, for the frequency and extent of extreme weather events through gradual changes in average temperature or annual average rainfall. In order to identify possible impacts and describe the climate-related risks that can arise, we need to be able to say something about what the climate will look like in the future in the geographical area we want to analyse. To aid these efforts, we use different climate scenarios that give us an indication of the kind of climate we can expect in the future.

The Swedish Meteorological and Hydrological Institute (SMHI) website contains climate analyses by county for all counties,[38] which provides a good starting point for the work. By studying how different climate indicators, such as annual average temperature, heat waves, growing season length, annual average rainfall, 100-year inflows or expected sea level rise, will develop according to different climate scenarios, we can get a picture of what the climate will look like in the future. On the Swedish Civil Contingencies Agency (MSB) website, event scenarios for climate-related challenges (landslides, torrential rains, storms, heat waves) have also been developed to support the work.[39]

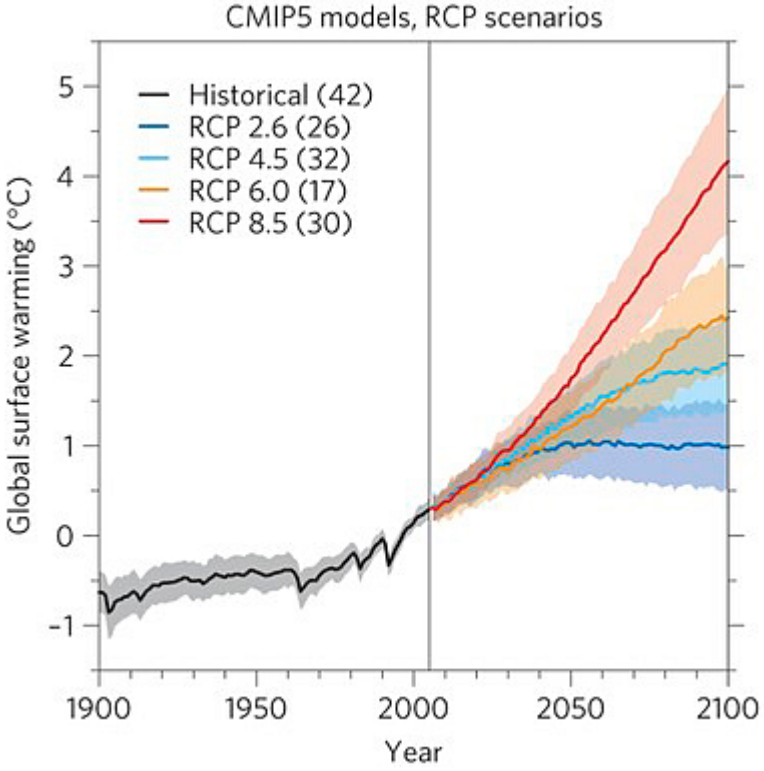
To understand which climate-related risks should be considered when implementing climate adaptation measures, a climate scenario[40] must be chosen to be included in the analysis. This is because different climate scenarios vary with regard to the extent of different climate impacts, necessitating an argument about which future climate change is relevant to provide scope for.

All representative concentration pathways (RCPs) are based on assumptions about greenhouse gas emission trends, land use (deforestation, etc.) and assessments of air pollutant emission trends (such as for sulphur dioxide and nitrogen dioxide).[41] It is these climate impact factors that are driving climate change today. They in turn depend on population trends, changes in energy use, economic growth and so on.

There are different potential RCPs for the climate. The climate scenario and time perspective that you choose to start from in your climate analysis play a role in the outcome.

[38] County-specific climate analyses, SMHI
[39] Klimatrelaterade händelsescenarier, MSB, msb.se
[40] Vilka klimatscenarier bör användas? SMHI
[41] Snabbguide till IPCCs RCP Scenarier, smhi.se

Figure 4. Examples of possible RCPs for global average temperature increase.
Source: SMHI, IPCC.



As Figure 4 illustrates, the choice of RCP does not make much of a difference until the middle of the century, after which the difference becomes clear. You can therefore choose a more positive or a more negative starting condition for our assumptions about future climate. The assessment of risk becomes central here, since risk itself is a function of probability and consequence. In all planning, the probability of an impact must be combined with its consequence. The more serious the consequence of an impact is assessed to be, the more important it is to also include scenarios based on continued high emissions of greenhouse gases.

When you have examined on an overall level how different climate indicators are assessed to evolve in the geographical area you are studying, the analysis can be scaled down to investigate what risks this creates. The report "Riskanalys i ÖP"[42] from the County Administrative Board of Västra Götaland contains a detailed list of available planning documents that serve as support for the risk analysis (flood risks and geotechnical risks). The section "Supporting documents and tools for identifying climate-related risks" in this document also contains several background documents that serve as input for identifying climate-related risks.

[42] Riskanalyser i ÖP, Västra Götaland County Administrative Board, lansstyrelsen.se

READING TIPS

These sources provide more guidance on climate scenarios and time perspectives:

- SMHI: Vägledning för användande av klimatscenarier
- SMHI and Swedish Environmental Protection Agency: Snabbguide till IPCC:s RCP-scenarier
- National Board of Housing, Building and Planning: PBL kunskapsbanken – Klimataspekter och tidsperspektiv

2 ANALYSE PROBABILITY AND CONSEQUENCES

Climate change studies often discuss long time horizons, such as weather averages over a 30-year period. Time perspectives are therefore central in risk analyses. Three different perspectives are appropriate: How is the area or activity currently being affected? How will the area or activity be affected in 2050 and how will it be affected in 2100? If deemed relevant, the analysis can extend beyond 2100, for example in the context of sea level rise.[43]

Afterwards, an assessment can be made about whether the impact is expected to be very small, small, medium or large. The probability of an event, such as a flood, occurring can be assessed on the basis of estimated return periods for a particular event above impact thresholds (Table 2). This can vary depending on the initial climate scenario you choose, so it is a good idea to perform the assessment based on several different scenarios.

Table 2. Examples of probability levels for when the impact of an event is assessed to occur.

Low	Less than once every 100 years.
Medium	Between once every 10 to 100 years.
High	Between one per year to one every 10 years.
Very high	Several times per year.

Source: SMHI.

To assess the consequence, a good starting point can be to look at events that have already occurred. If the assessment has identified that the occurrence of torrential rains is expected to increase in a future climate, the consequences of previous floods can be investigated. Next, an argument can be made about which consequences the event could have if it occurred in the middle of the century or at the beginning of the next. It is also important to understand how future climate change will affect what we today define as torrential rains or extreme rains.[44]

[43] Sea levels will continue to rise even after 2100, regardless of the climate scenario. It might therefore be reasonable to consider projections for sea level rise extending beyond 2100 when designing appropriate measures.
[44] Klimatrelaterade risker i översiktsplanering – metodstöd, lansstyrelsen.se

3 ASSESS RISK

Using the collected information about what the conditions look like today for managing potential risk, how we assess the risk, and the assessed probability and consequences, we can make an overall assessment of which risks should be the highest priority. The results of the assessment should also indicate the underlying causes of the identified risks.

Once you have investigated the climate impacts on the area or activity and the risks they pose, and have prioritised the most important ones to manage, you can use this information as supporting documentation in the subsequent steps of identifying and selecting the appropriate measure. The climate risk and vulnerability assessment also enables the correct use of resources and should serve as input for follow-up after the action is implemented. There are several different methods for analysis and assessment, and the project's conditions should determine which method is selected. It is also important to document the assessment, regardless of whether or not documentation requirements exist according to the Ordinance (2015:1052) on Emergency Preparedness. The methodology, underlying data, selected calculation parameters, assessments and assumptions made should be clearly justified and reported. In this way, the risk assessment becomes transparent and can be followed even by those who have not participated in the work.

Risk assessment at the municipal level

Climate-related risk in the master plan

The municipal master plan is the municipality's most essential instrument for providing guidance on how to adapt existing and future buildings and infrastructure to the effects of climate change.[45] In the plan, clear positions and priorities can be made to reduce climate-related risks and avoid costs down the road. Issues relating to more frequent precipitation or heat waves in a changing climate are, for example, best managed early on during high-level planning. Strategic considerations that support climate-adapted municipal planning will also play an important role in managing climate risks in existing buildings, since they are already included in the detailed development plan. In this way, the municipality can, through the master plan, steer towards sustainable land and water use and management of climate-related risks, both in high-density environments and the surrounding landscape.

According to the Planning and Building Act ("PBL"), municipalities must address climate adaptation in their master plans.[46]

This can be done by identifying risk areas (such as low points) for flooding, avalanches, landslides and erosion resulting from higher flows in lakes and watercourses, torrential rains or sea level rise.[47] This information can be considered when identifying suitable areas for construction and development. It can also be used to develop goals and strategies for how to preserve and enhance green infrastructure in order to manage factors like stormwater or high temperatures.

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[45] Klimatanpassning i planeringen, PBL kunskapsbanken, National Board of Housing, Building and Planning

[46] Under the 2018 amendment to the Planning and Building Act, Chapter 3, Section 5, municipalities must in their master plans describe their views of the risk of damage to the built environment that can result from flooding, avalanches, landslides and erosion that relate to climate, as well as how such risks can be reduced or eliminated. Planning and Building Act (2010:900), Swedish Code of Statutes SFS 2010:900 through SFS 2020:603, Riksdagen

[47] Master plan contents, PBL kunskapsbanken, National Board of Housing, Building and Planning

The master plan also provides for the possibility to address climate-related challenges in a broader perspective, since adaptation issues often need to be coordinated regionally and across municipal boundaries.[48] For example, this could involve studying the challenges of flooding spanning an entire river basin area, or several detailed development plans. Appropriate measures for managing flood risk in the built environment might need to be dealt with upstream in a catchment area through the restoration of watercourses, or the construction of wetlands or other infiltration basins. Suitable land for such measures can therefore be identified in the master plan in order to pursue these types of nature-based solutions in future planning. The master plan can also identify areas or challenges that require in-depth investigations to be carried out. The accounting of risks then forms the basis of the impact assessment carried out in the master plan. The risk assessment will also be part of the environmental impact assessment (EIA) to be drawn up when the plan is developed.[49]

Sometimes, however, the master plan might be too general for addressing the complex issues and trade-offs around climate adaptation measures in the municipality. Through an in-depth master plan or a plan programme, a higher level of detail can be allowed within a smaller geographical area to solve issues like stormwater problems.[50]

Furthermore, since 2018 there has been clearer support than before for dealing with climate adaptation issues in EIAs based on the definition of environmental impacts in Chapter 6, Section 2 of the Environmental Code.[51] The climate aspect, meaning emission reductions as well as climate adaptation, must be integrated in the entire EIA process for both plans and programmes.

Examples of support for managing climate-related risks in the master plan include the County Administrative Board of Stockholm's *Metodstöd för hantering av klimatrelaterade risker i översiktsplanen ("Methodological support for managing climate-related risks in the master plan")*[52] and *Checklista för klimatanpassning i fysisk planering ("Checklist for climate adaptation in spatial planning"),*[53] developed by the county administrative boards.

Regional climate adaptation plans

The climate adaptation plans developed by all county administrative boards (2014) are being updated according to the new requirements stipulated by the Ordinance (2018:1428) on climate adaptation efforts by public authorities and can also support the efforts. The ordinance states that a climate risk and vulnerability assessment must be made for the county administrative board's entire scope of operations and must identify vulnerable areas requiring climate adaptation measures.[54] The plans are a vital aid and input in efforts to identify climate-related risks in each county and to manage climate adaptation challenges from a broader, inter-municipal perspective.

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[48] Klimatrelaterade risker i översiktsplanering – metodstöd, County Administrative Board of Stockholm, lansstyrelsen.se

[49] Mångfunktionella ytor: Klimatanpassning av befintlig bebyggd miljö i städer och tätorter genom grönstruktur, boverket.se

[50] Klimatanpassning i planeringen, PBL kunskapsbanken, National Board of Housing, Building and Planning

[51] Klimat i miljöbedömningar, naturvardsverket.se

[52] Klimatrelaterade risker i översiktsplanering – metodstöd, County Administrative Board of Stockholm, lansstyrelsen.se

[53] Fakta 2016:7 Checklista klimatanpassning i fysisk planering.pdf, lansstyrelsen.se

[54] Ordinance (2018:1428) on climate adaptation efforts by public authorities. Swedish Code of Statutes 2018:1428, Riksdag

Municipal climate adaptation plans

Many municipalities already have climate adaptation plans in place that serve as excellent planning input for strategic decision-making and as supporting documents for the master plan, detailed master plan, detailed development plan or plan programme. The climate adaptation plan can be advantageously used to dig deeper into identifying the climate-related risks faced by the municipality and ways to manage them.[55] Heat-related challenges, flooding, stormwater management or sea level rise, for example, can be highlighted. An adaptation plan can also include a specific review of how planning and management function relative to the municipality's handling of climate adaptation issues. An example of a municipality that has developed an action plan for climate adaptation is Örebro Municipality.[56]

Stormwater management at municipal level

Public stormwater management in a municipality is a municipal matter primarily regulated by the Environmental Code, the Planning and Building Act and the Public Water Services Act. Yet legislation on municipal stormwater management is often complex and difficult to interpret.[57] Developing a plan for torrential rains and stormwater in stormwater strategies and policies can help clarify oversight for management and, in the long run, reduce both the load on municipal treatment plants and the risk of flooding during heavy rains. For example, a policy can state that the municipality should always try to implement improvements to manage stormwater during torrential rain events, preferably with green solutions when converting public lands. Through torrential rainfall plans and mapping, the issue of torrential rains in a changing climate can be further investigated. Mapping and modelling of low points or other vulnerable places in municipalities can be used to determine the impact risk from different types of torrential rains (intensity and return period), today and in the future. An example of a municipality that has developed a torrential rain mapping is the City of Stockholm.[58]

[55] Mångfunktionella ytor: Klimatanpassning av befintlig bebyggd miljö i städer och tätorter genom grönstruktur, boverket.se

[56] Klimatanpassningsplan, Örebro Municipality, orebro.se

[57] Handläggarstöd om dagvatten, report, lansstyrelsen.se

[58] Stockholms skyfallsmodell, Stockholms miljöbarometer

Green plans

Green plans can also be created at the municipal level. These are a combination of an action plan for developing and managing green infrastructure in the municipality according to the overarching objectives of the master plan, and planning input with mappings of the values and functions of existing green areas and natural environments. The green plan can consist of one or more documents. Although there is no legal requirement for a municipality to have a green plan, many of them do. Such plans provide crucial support in efforts to, for example, identify climate-related risks where climate adaptation measures linked to green infrastructure are reported. "Green plan" is a collective term for nature conservation plans, park programmes, game management plans and similar planning documents.[59]

Supporting documents and tools for identifying climate-related risks

A considerable number of guides, background documents, GIS layers and mapping display tools are available that can be used as an aid when mapping areas where climate-related risks are present. The following box contains tips on tools and supporting documents to use in climate adaptation efforts and climate risk mapping. (See also the box on page 43).

[59] Ta fram en grönplan, PBL kunskapsbanken, National Board of Housing, Building and Planning

TIPS tools and supporting documents

- **Collected climate adaptation data on the Swedish Environmental Protection Agency website**

  On the Swedish EPA's webpage for climate adaptation, you can find a list of current supporting documents containing data and support for climate adaptation efforts in different areas (sea level rise, torrential rains, flooding, avalanches, erosion, heat waves, wildfires and more).

- **Geodata for climate adaptation – Practical training**

  This mapping report gives you valuable information about how different GIS data can be used in climate adaptation work and risk assessment during spatial planning. The documentation has been developed through the government network for climate adaptation.

- **Climate event scenarios – MSB**

  The Swedish Civil Contingencies Agency (MSB) website contains support for climate-related risks in municipalities or activities based on several event scenarios (avalanches, landslides, storms, heat waves). The event scenarios are a tool that can be used in climate adaptation and risk management efforts on a strategic level.

- **Climate adaptation in spatial planning**

  The county administrative boards have developed a guide to make it easier for municipalities to integrate climate adaptation issues in spatial planning serve as an aid in the review of municipal physical plans from an adaptation perspective.

- **Checklist for climate adaptation in spatial planning**

  This checklist supports the county administrative boards when they review master plans and detailed plans in relation to how they have considered the effects of climate change. It can also support the municipalities in developing these plans.

- **Climate risks in master planning – methodological support**

  This methodological support is aimed at municipalities to enable them to easily design their work processes for climate-related risks and the supporting documents that must be developed. It contains guidance on how geological, geotechnical and topographical data such as mappings for sea level rise, flooding avalanches and landslides can be used. The methodological support also proposes different types of risk management measures that can be described in the master plan.

READING TIPS

- **Multifunctional surfaces – Climate adaptation of existing built environment in cities and urban areas through green infrastructure**
  Guidance from 2010 by the National Board of Housing, Building and Planning on multifunctional surfaces that provides valuable input for designing the work on nature-based solutions within the framework of municipal spatial planning efforts.
- **Mapping of buildings at risk of overheating – Public Health Agency of Sweden**
  Guidance providing a methodological description for how to map buildings at risk of developing dangerously high temperatures
- **Managing the health effects of heat waves – guidance for Action plans – Public Health Agency of Sweden**
  Guidance containing support tools and recommendations for municipalities, county councils, regions and private stakeholders in developing action plans for bolstering capabilities to manage the adverse health effects of heat waves.
- **PBL Kunskapsbanken**
  National planning board guidance for the Planning and Building Act ("PBL") provides general spatial planning support based on steps in the planning process or on different themes. For example, it contains a section on health, safety and risks and one on ecosystem services in the built environment that can be relevant to consult in this context.
- **"Planeringskatalogen"**
  Planeringskatalogen is a database that gathers in one place all relevant planning documents, guidance and geodata for land use planning from different websites, portals and databases.
- **SMHI's climate webpages**
  Here you can find information about how and why the climate is changing, how it is affecting society and how we can adapt to climate change.
- **Klimatanpassning.se**
  This is an online portal that provides support for people working on adapting society to climate change.


Interest organisations?
Land-owners?
Residents?
Culverted watercourses
Gravel fill

Step 2. Identify and understand the socio-environmental context

When identifying risks, it is also important to understand the social and environmental context within the area or landscape that the action focuses on. An understanding of how biodiversity, consisting of species and ecosystems, provides ecosystem services in a landscape is central to planning and implementing nature-based solutions. Knowledge of biodiversity and ecosystem services helps us understand how and where conservation, restoration of existing ecosystems or the creation of new ecosystems has the greatest potential to contribute to the landscape's climate adaptation.

For example, wetland restoration or watercourse re-meandering can bolster nature's own capacity to retain water in the landscape. At the same time, information about the environmental and social nature of the landscape is needed in order to correctly design the solution. If this information is lacking, you risk not generating the ecosystem services planned. In the worst case, you can make the situation even worse. Identifying and understanding the environmental and social conditions is thus crucial for enabling a nature-based solution to provide the intended benefits and to function over time. Parts of this step might therefore need to be implemented earlier in step 1. As already mentioned, steps 1 and 2 are closely linked.

By understanding which areas, environmental functions and connections should be prioritised and emphasised in the landscape, we can also help leverage and enhance the conditions for implementing and preserving nature-based solutions.

The goal of step 2 is to identify the characteristics of the area or landscape in focus, in order to establish an understanding of the conditions for pursuing nature-based solutions. The description should include both the type of biodiversity that characterises the area and the ecosystem services that it provides, how the area or landscape is currently being used, who uses, influences and depends on it, and who oversees its management and development. Understanding how the landscape or area is relevant for the people associated with it in different ways is essential for the assessment.

So in this step, it is important to get a picture of the area's values (nature values, environmental functions, recreational areas, production) as well as how the area is used. The plans being developed for the area (high nature-value areas, master plans, land acquisition plans, management plans) will serve as guidance here.

In this step, the following questions will be answered:

- What does the area look like from an environmental and a social perspective? What are the habitat types in the area and what does the topography look like? How is the area used and by whom? Which ecosystem services come from the area?
- Does the area have existing climate adaptation targets?
- Who are the stakeholders? Landowners, residents, interest groups?
- What advice and guidelines are there for implementing measures – landowners, communities, area protection, plans, others? Economic conditions also come into play here.

Mapping the area

The natural conditions in the area give an indication of, and framework for, the climate adaptation measures that can be appropriate, whether nature-based solutions, grey infrastructure solutions or a combination of the two. Therefore, it is important to access supporting documents about the area such as ordinary maps, nature value inventories and plans (master plans, green plans, green infrastructure plans). In terms of species and ecosystem knowledge, much data is available that can support the assessment. Some of these data sources are presented at the end of this section, such as regional plans for green infrastructure and information about species in the Swedish Species Observation System. But in some cases, specific inventories might need to be carried out in order to gain new knowledge that has not yet been mapped.

ECOSYSTEM SERVICE MAPPING

Ecosystem services in the area can have been mapped in a municipality's supporting documents for the master plan, for example.[60] However, ecosystem services in the area or landscape in question might need to be mapped for the first time. When mapping ecosystem services, you might need to look at the ecosystems and their services from a landscape perspective, rather than only in the delimited area being targeted for climate adaptation. This is because ecosystem services can provide benefits both locally and regionally, and in some cases even globally. Enabling the optimal planning and siting of an action might involve investigating the hydrological conditions in an entire catchment area, if the problem to be addressed involves the ecosystem service of water management. Another example is how natural areas, even those without lakes or watercourses, are important for stormwater infiltration and can thus become a vital retention basin for minimising the risk of flooding in buildings. Identifying and mapping the natural climate-regulating functions of ecosystems in the relevant landscape will therefore be central.

However, since an ecosystem usually provides multiple ecosystem services, it is important to draw attention to the other ecosystem services that exist and that affect the outcome of the measure for the whole.

Once the ecosystem services have been mapped, the next step is to analyse and visualise the values they generate in an ecosystem service analysis.[61] Here, a link can be made to how ecosystem services contribute to society's well-being, and how these values can be affected by various alternative measures. The process results in decision-making input that indicates existing values in the area, how they can be positively affected by a measure and what considerations can be taken to reduce negative impact. This step involves mapping, and it is not until step 4 (solution prioritistion) that an ecosystem service analysis should be carried out. So, a more detailed description of ecosystem service analysis is available in the section on the valuation and visibility of benefits.

[60] Upplands Väsby, Kartläggning av ekosystemtjänster, upplandsvasby.se
[61] Ecosystem analysis, PBL kunskapsbanken, National Board of Housing, Building and Planning

CASE LOMMA MUNICIPALITY

Inclusive participatory process for coastal zone programme in Lomma

In Lomma Municipality, a programme has been developed for the integrated management of the municipality's coastal zone, taking into account the expected sea level rise, and with a special focus on ecosystem services. This process was selected as a case study within the framework of the research programme ECOSIMP partly to study the participation of different stakeholders in the process, especially with regard to the interaction between the municipality and citizens. The municipality wanted to create a co-responsibility and open up for joint work around the coastal zone and therefore came to involve the local Coastal Waters Council early in the process. The Coastal Waters Council consists of different user groups, including fishermen, windsurfers, kitesurfers, boat owners, bird-watchers and nature organisations. Municipal planners view the Council's involvement early in the process as something new, and different from the mandatory consultation process in spatial planning which many perceive takes place too late to make any real impact. Instead of approaching citizens and other stakeholders with a finished product, the planners laid the foundation for a transparent collective effort.

▶ Read more here.

Involve stakeholders

Stakeholders should be identified and involved in step 2, unless this was already done in step 1. Who is affected by the planning, implementation and subsequent maintenance, and who will benefit from the measure? It can also be interesting to identify who is affected if an adaptation measure is *not* implemented, which would also be an important part of the risk analysis described in step 1.

There might be numerous stakeholders who represent different interests depending on the climate challenge to be addressed, the scale of a potential solution's implementation and other functions, nature-based or otherwise, that the solutions can provide.

CASE – ÄNGELHOLM MUNICIPALITY

Citizen initiative in Ängelholm became a nature-based solution

In Vejbystrand in Ängelholm Municipality, the coastline is heavily affected by erosion. One of the municipality's residents proposed a nature-based solution in the form of sand fencing made of willow sticks woven together to protect the dunes. The proposed initiative was submitted in 2014 and, following a political decision on the matter and subsequent budget process, the permit process could begin. In the end, approval was granted to erect the fencing. Today Vejbystrand has three fences, each 100 metres long. A follow-up study found that sand fencing has a positive effect on reducing beach erosion.

Eva Thulin submitted a citizen initiative for the sand fencing that became a reality in Ängelholm Municipality.
Photo: Niklas Gustavsson, Helsingborgs Dagblad.

In this context, stakeholders range from municipal and regional experts in a variety of management roles (planners, landscape architects, construction and water/wastewater engineers, municipal ecologists, management contractors, educators) and landowners to various interest groups and residents.

In order to increase a measure's multifunctionality, stakeholders must be involved early in the planning process. For example, a local association can have in-depth knowledge of an area not documented in existing documentation, such as how the area is used or whether it is home to species having special requirements for their surroundings. In this case, the solution can be designed to preserve these values in some form so that the area can fulfill multiple functions.

So involving an array of stakeholders at an early stage in the planning process creates benefits such as a broad use of skills, a good starting point for understanding the problems to be addressed and an early acceptance of possible solutions. Mapping and stakeholder engagement are also a crucial component in the successful implementation of nature-based solutions in subsequent steps.

Oversight, responsibilities and frameworks

Under the national strategy for climate adaptation, responsibility for the protection of property through climate adaptation measures lies primarily with property owners.[62] Depending on the challenge in focus and the area affected, there are of course different stakeholders who have or can take on responsibility for implementing measures. This responsibility is often based on legislation (right of ownership) in which the responsibility for protecting property lies primarily with the property owner and the owner's insurance company.
Sectoral goals, policies and plans or ordinances – often national but sometimes international – also play a role here. Clarifying responsibilities and oversight for measures among landowners, communities, municipalities, county administrative boards and other authorities is central to efforts in subsequent steps. This is mainly because many nature-based solutions require large swaths of land to reach their full potential, thus affecting many stakeholders. Furthermore, oversight and liability are a key component because a climate adaptation measure is not necessarily best suited to the problem area itself, like a flooded residential area, but higher up in a catchment area, for example in a degraded wetland area in a neighbouring municipality. So even though the responsibility for climate adaptation lies with the individual owner of the land and property, another stakeholder might have oversight for the optimal climate adaptation solution. Determining oversight, responsibilities and frameworks thus also involves coordinating, engaging and informing stakeholders to address these types of challenges.

Oversight for the municipality's scope of action regarding climate adaptation is also guided by the so-called principle of equality. According to this principle, a municipality cannot provide the funding for an installation or activity aimed at protecting individual interests.

This means that it can be difficult for a municipality to implement a climate adaptation measure where the benefit only accrues to an individual or a group

[62] Govt. Bill 2017/18:163: National strategy for climate adaptation, riskdagen.se

of municipal residents.[63] If the municipality will provide funding in such a case, citizens in the same situation in another part of the municipality must be treated equally.[64]

However, in cases where the public interest would also be protected by a measure, a municipality can provide funding. This can open up the possibility of implementing a nature-based solution because, depending on its design, it can be used as a recreational area or to enhance an area's biodiversity. The solution's significance for serving the public interest must be clarified and quantified.

Planning conditions should also be clarified. For example, does the master plan, detailed development plan or other governing planning documents contain support for implementing a particular measure? As described in step 1, the master plan can become a vital planning instrument for enabling the implementation or preservation of nature-based solutions in a municipality. Positions or statements on including nature-based solutions when evaluating redevelopment or planning new environments also act as enablers for these solutions. Such positions in plans and strategies can thus set a precedent, for example, in the detailed plan.

In some cases, when the municipality specifies boundaries for sites, development districts and water areas, the detailed development plan can also serve as a tool.[65] The detailed planning process offers the opportunity to provide scope for creating sufficient public space for managing stormwater, or for regulating ground elevation in the planning area to divert torrential rains to recipients or to planned infiltration basins, such as a stormwater runoff park.[66] The detailed development plan can also promote good conditions for minimising and managing stormwater by enabling a municipality to regulate the degree of impervious cover.[67] In special cases, the municipality can also decide in the detailed development to require a land permit for land-use measures that might impair land permeability.[68]

This does not entail provisions that specifically regulate the introduction of nature-based solutions in spatial planning, but rather could be used to create the right conditions for promoting these types of measures.

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[63] Finansieringsmodeller_för_klimatanpassning_slutversion_200519, swedgeo.se

[64] Local Government Act (2017:725), Planering för bostadsförsörjning, National Board of Housing, Building and Planning

[65] Vad är en detaljplan, PBL kunskapsbanken, National Board of Housing, Building and Planning Säkerställ ekosystemtjänster i detaljplan, PBL kunskapsbanken, National Board of Housing, Building and Planning

[66] Appendix 1: Dagvattenhanteringen idag, naturvardsverket.se

[67] Dagvatten vid detaljplaneläggning, PBL kunskapsbanken, National Board of Housing, Building and Planning

[68] Marklov, PBL kunskapsbanken, National Board of Housing, Building and Planning

TIPS Documentation and support

Here are some tips on documentation and support that can be useful during mapping and analysis of natural values in the area. The documentation presented at the end of step 1 can also support the analysis in this step.

- **Regional plans for green infrastructure**

  All county administrative boards have developed plans for green infrastructure that serve as supporting documents for landscaping in the use and sustainable management of land and water as well as for consultation and collaboration among various stakeholders. These regional plans serve as both decision and planning support documents for ongoing land and water use, as well as input for spatial planning and environmental review.

- **National land cover database**

  Land cover mapping serves as vital input to the work on biodiversity, sustainable land use, ecosystem services, built environment and land-use planning, and climate and vulnerability. The Swedish EPA, in collaboration with several state agencies, has developed a nationwide land cover database, (the "NMD").

- **National map layers with HNV areas**

  High nature value (HNV) areas are a cornerstone of the county boards' green infrastructure efforts. This map layer contains high nature-value areas for many nature types across much of the country.

- **Protected Nature mapping tool**

  The Protected Nature ("Skyddad natur") mapping tool contains information about protected areas in Sweden and Sweden's Natura 2000 sites. National protection plans or designated in international conventions are part of the mapping tool.

- **Ecosystem services (naturvardsverket.se)**

  The Swedish Environmental Protection Agency's webpage on ecosystem services contains several relevant guides: there is one guide for ecosystem services in environmental assessments and another for integrating ecosystem services in government activities. It also contains a guide for evaluating ecosystem services, a link to guidance from the National Board of Housing, Building and Planning on ecosystem services in the built environment, and other useful materials.

- **The Swedish Species Observation System**

  The Swedish Species Observation System is a portal for reporting and searching for species observations in Sweden. It is an open system, accessible to anyone.

READING TIPS

Here are some tips on documentation and support that can be useful during mapping and analysis of natural values in the area. In addition to these, the supporting documents presented at the end of step 1 can also support the analysis in this step.

- **Biodiversity survey**

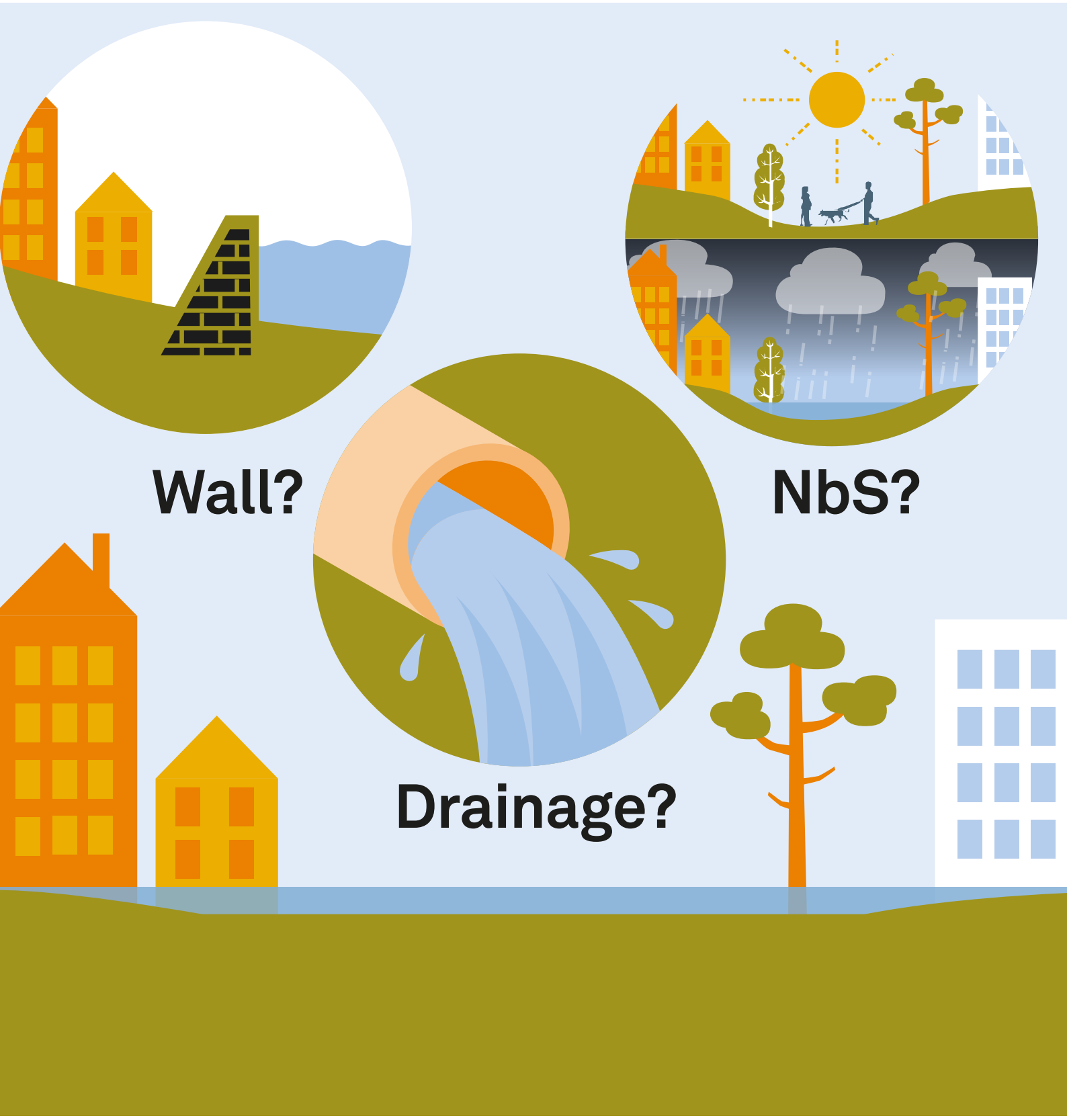
  To facilitate the procurement process and quality assurance, the Swedish Institute for Standards (SIS) has developed standard SS 199000 for taking surveys of nature conservation values related to biodiversity. The standard contains basic requirements on performance and expertise and provides guidelines for uniform terminology.

- **VISS – Water Information System Sweden**

  VISS contains classifications and maps of Sweden's major lakes, streams, groundwater and coastal waters.

- **Reindeer husbandry plans**

  These plans are used by the Sami community to describe their land use. They are used in high-level planning and environmental impact assessment, as well as in detailed plans during consultations and dialogues.


Wall?
NbS?
Drainage?

Step 3. List possible solutions

Once the climate-related risks are identified and the environmental and social conditions mapped, it's time to identify and evaluate possible solutions together with the stakeholders involved. Most often, there are several potential solutions for addressing a specific climate challenge including nature-based solutions, grey solutions, or a combination of both.

The solution to a problem might even involve implementing a measure in a different geographical location than that of the problem area itself. This is why it is crucial to take a landscape perspective and look at the geographical conditions for determining potential solutions.

The goal of step 3 is to develop a list of possible measures and strategies that can reduce the climate-related challenge being faced. The list should include all potential solutions, whether traditional grey or nature-based, and provide an overview of the measures' effects for both direct and indirect advantages and disadvantages. This supporting document is input for the priorities and choice of measures in the next step. Stakeholders should preferably be involved in developing the list and a landscape perspective should be adopted, since the solution can be in a different geographical location from the problem area.

It is important to look at how well the different options can help achieve other objectives (multifunctionality), to clarify how biodiversity and ecosystem services might be affected and to ensure that the measure does not compromise biodiversity. It is also vital to consider how the solution will function over time, and to clarify any issues regarding resource use, testing and funding.

Some measures can be easier to implement directly while others can require permits, such as building permits, which can take time. In terms of funding, it might be possible to apply for external funding for implementation. Although this takes time, too, it presents an opportunity that can facilitate implementation. The purpose of this step is not to conduct a permit procedure or seek funding or to carry out an ecosystem service or valuation analysis. (These steps will be done a bit later.) However, it might be helpful to perform an initial analysis in these respects to have as supporting documentation for future priorities. In this way, steps 3, 4, and 5 are linked together, and we recommend several check-off points between the steps to see which parameters need to be clarified or described as a base level (or heading level) in this step. The process is needed in order to get a basic grasp of a solution before one is actually chosen and the implementation phase begins.

Ensure participation

An open, transparent process that takes a holistic perspective is preferable for encouraging participation and increasing the multifunctionality of the solution. As described in the previous section, broad participation from different stakeholders will help in identifying possible solutions and ensuring that the chosen solution is multifunctional. For example, a local association might have information about how an area is usually used for recreation, or about the presence of species that warrants special consideration.

Participation, whether in consultative processes or other forms, is also vital for understanding whether a solution provides adequate protection for people's security and well-being, or whether a combination of solutions is needed to achieve the primary objective. An open process with clear communication and dialogue often creates understanding, but it is particularly important for finding a solution that helps to achieve multiple goals and a variety of stakeholder needs.

Spatial scale

Different climate-related risks may need to be managed at different spatial scales. For example, if there is a risk of flooding, an entire catchment area may need to be considered when choosing a solution. It is also possible that a measure can affect surrounding land areas and environments. In general then, it is good to take a more comprehensive perspective – a landscape perspective – so that all the effects of a measure are captured.

Multifunctionality: advantages and disadvantages

The benefits should be listed for each of the proposed measures, including those related to other societal challenges. The major added value of nature-based solutions is that when designed thoughtfully, they can provide other values and thus be multifunctional. A key starting point for nature-based solutions is that they should not negatively affect biodiversity but rather enhance it. Giving visibility to these values early in the process is especially important for building synergies with other stakeholders who can be affected by the added value. The idea here is not to conduct an in-depth ecosystem service analysis for every potential solution in this step; this will be done in step 4. However, in order to form a basic idea of the various potential solutions, the benefits including added value must be described at this stage.

In this step, it is necessary to note any disadvantages and risks a measure can bring. For example, does the soil contain contaminants that are at risk of spreading during material mass excavation and transport? Does the risk of fire increase when installing a green roof and wall? Could a patch of wetlands become an unintended pathway for invasive non-native species? Any competing interests in the area should also be identified and explained in this step. Does a nature-based solution prevent others from using the same area for other purposes, such as for recreation, reindeer grazing or farming?

It should be emphasised that nature-based solutions can be implemented either independently as a solution to a specific problem or in combination with other solutions of a more technical nature. For example, installing rain gardens can reduce the load on existing stormwater facilities, whose stormwater dimensioning for a future climate risks becoming both complex and costly. Figure 1 and Chapter 4 contain examples of what a nature-based solution can look like, offering more inspiration from implemented measures in different types of landscapes.

Time horizon

It is necessary to understand the advantages and disadvantages in both the short and long terms. Establishing a nature-based solution can take time, so it can take some time before it achieves its full impact. This is a key difference between planning a nature-based solution and a traditional grey solution.

The time aspect is also interesting from a maintenance perspective. Different types of solutions usually require different types of maintenance. Maintenance of a nature-based solution can involve continuous management, while an engineered solution might require longer service intervals of several years. It is prudent to reflect not only on the costs, but on responsibility for managing the solution.

At this stage, it is also important to consider how the measure should be followed up and its effectiveness evaluated. The follow-up itself takes place when the measure is implemented. But at this stage, it already makes sense to try and specify the parameters that could be followed up relative to what the measure will deliver, and whether there are appropriate indicators, methods or ongoing monitoring systems that can be used for follow-up. You can read about more about follow-up and evaluation of implemented solutions in step 6.

Sustainable resource use and footprint

A measure that aims to adapt communities to a changing climate should not enhance carbon emissions. So, it is important to take a look at material use and possibly the footprint. Which materials will be needed for the measure? Are the processes energy-intensive? Assessing the sustainability of the measure over time and the need for management and maintenance are also relevant.

Reviewing the measures

Many measures, both nature-based and grey, can require some form of review. For example, activities that fall under the Environmental Code or measures planned in locations covered by coastal or biotope protection legislation must be granted an exemption from the responsible body (usually the county administrative board or the municipality). Depending on where in the landscape the measure will be implemented, permission might also be necessary through a detailed development plan or building permit. For activities affecting reindeer husbandry, consultations must take place at an early stage with the Sami Parliament and relevant Sami communities.

CASES

Coastal protection exemption for nature-based solutions

If you intend to pursue a nature-based solution that requires an intervention in a protected coastal area, you must apply for an exemption from the county administrative board or municipality.

For example, the intervention could be the removal of invasive non-native species along a coastline with the aim of re-creating a dune environment with native species. This requires a coastal protection exemption since it involves a measure that changes something within the protected coastal area. Usually, it is the municipality that decides whether or not to grant an exemption. The decision is then sent to the county administrative board for review. Photo: Anki Weibull.

- Read more about the reasons for coastal protection exemptions.

READING TIPS

Examples of legislation and activities that can be grounds for a permit procedure.

- **Coastal protection**

  Coastal protection aims to secure the right of public access to coastal areas for the long term, and to preserve healthy habitats for animals and plant life both on land and in water. An exemption from coastal protection can be required. The Swedish EPA provides guidance.

- **Biotope protection**

  Biotope protection areas are areas that due to their specific characteristics are valuable habitats for endangered animal or plant species. Some biotopes have generally applied protection, and others are decided on a case-to-case basis. An exemption can be required. The Swedish EPA provides guidance.

- **Municipal plans**

  What does the master plan say? Is the site covered by a detailed development plan? Does the measure require support in the master plan or the detailed development plan?

  Is a municipal green plan available? Are there other plans, such as a conservation plan, which are governing? The National Board of Housing, Building and Planning provides guidance.

- **Land permits**

  Under the Planning and Building Act, land permits can be needed for measures within the planned area, such as excavation or the felling or planting of trees. The National Board of Housing, Building and Planning provides guidance.

- **Water operations**

  Any measure that has an impact on or takes place in water constitutes a water operation that must be reported or undergo a permit process. The Swedish Agency for Marine and Water Management provides guidance.

- **Land drainage**

  Land drainage is a water operation that always requires a permit, and any changes to an existing ditch can require a permit. Installed land drains are managed by an association or a private company in charge of operation and maintenance. The Swedish EPA provides guidance.

READING TIPS

- **Protected areas (Natura 2000, nature reserves and other protected areas)**

  The Swedish EPA's mapping tool Protected Nature[69] shows which Swedish areas are included and why they have been selected. It contains maps and lists of species affected and their location. Note, however, that the presence of certain endangered species has been eliminated for safety reasons. The Swedish EPA also offers guidance on the rules that apply within a protected area.

- **Species protection**

  Species protection applies throughout the country and is a complement to the different area protections.

  Species protection implements international agreements and EU directives and also covers the Swedish protections. The Swedish EPA provides guidance.

- **Cultural heritage environment**

  A cultural heritage environment refers to an entire environment that is affected by human activity. It can be a designated site of national interest, part of master plans, cultural heritage programmes or be under protection through building heritage designations, nature reserve provisions or provisions in a detailed development plan. Effects on the cultural heritage environment, landscape and buildings are among the factors to identify, describe and assess for an environmental assessment. This is required under Chapter 6, Section 2 of the Environmental Code.

Costs and funding opportunities

A measure can incur different types of costs. Costs can arise from land purchases or the cost of compensation, and in the construction or restoration phase. Finally, operation and maintenance costs must be considered. It is a good idea to include the total costs over time, since a sustainable measure should be functional well into the future. When the time horizon is taken into account, you will note that large upfront costs for compensation or land acquisition can be compensated by low maintenance costs.

Basically, nature-based solutions show a huge potential for being cost-effective because, when properly designed, they contribute to economic, environmental and social sustainability.[70] In step 4, you can read more about how nature-based solutions can be evaluated. Sometimes a climate adaptation measure can help reduce the risk of flooding for several different properties at the same time, for example. So in these cases, responsibility should be shared among those who benefit. According to the Joint Facilities Act (1973:1149), an individual property owner can be forced to be jointly responsible for a shared facility if the benefit accrues to several properties.

To be a joint facility, the facility must be of material importance to the properties and the benefit must exceed the costs. For example, communal facilities can be formed for common purposes, such as green spaces, or for nature-based water

[69] Skyddad natur, naturvardsverket.se

[70] The solution is in nature, Future Brief 24, 2021, europa.eu; A Cost-Effective Approach for Disaster Risk and Water Resource Management, worldbank. org; Reguero et al. 2018.

management facilities like a constructed wetland. But if a nature-based solution will be introduced as a joint facility, the benefits that accrue to the property owners, and not primarily to the public,[71] must be explained.

APPLYING FOR FUNDING FOR NATURE-BASED SOLUTIONS

There are a variety of paths to take when applying for external funding to initiate an NbS action. The option you choose depends on factors like the type of measure, its purpose, who will implement it, and the spatial scale it should be implemented on. Below are some examples of cases where you might seek external funding for pursuing nature-based solutions. A more detailed description can be found in the appendix on funding.

TIPS funding opportunities

Some potential funding opportunities for nature-based solutions:

- LIFE – grants for environmental, climate-related and nature projects (naturvardsverket.se)
- Local Nature Conservation Program (LONA)
- Local Water Conservation Projects (LOVA)
- Investment grants for reducing emissions of pollutants in stormwater
- Grants for the remediation of contaminated areas to promote housing construction
- MSB – Government grants for preventive measures against natural disasters
- Interreg European Regional Development Fund (ERDF)
- Rural Development Programme (wetlands)

[71] Community facilities, National Land Survey, lantmateriet.se

Step 4. Prioritise a solution

After the different options are clarified, the consequences of the different solutions must be analysed to provide support in your choice of solution or solutions to prioritise.

Spatial planning has a well-established tradition of creating engineered grey infrastructure solutions, such as impermeable protective embankments and culverted watercourses for managing climate-related challenges like flooding or erosion. This means that these types of solutions are often documented, evaluated and widely known and therefore often take precedence during planning. Nature-based solutions, in turn, are a new concept that often lack comprehensive, systematic evaluations of their effects on a larger scale. This lack of comprehensive evaluations means that nature-based solutions feature a higher degree of uncertainty and risk being opted out of when different solutions must be prioritised.[72] Clarifying the multifunctionality and range of benefits a well-planned nature-based solution can offer can be critical for prioritising this type of solution over a grey solution. Examples of nature-based solutions in different landscapes and the ecosystem services they can provide (here divided into main benefits and co-benefits) are illustrated in Figure 5.

It might also be that success lies in a combination of several solutions – combining a grey solution with a nature-based solution, or using several different nature-based solutions to achieve the goals. Several small-scale measures, such as planting trees in a city, preserving green spaces, or installing rain gardens and stormwater runoff parks, can together help reduce the load on existing stormwater facilities. Therefore, it is important to look at the overall impact that the solutions can provide over a larger area and summarise their effects.

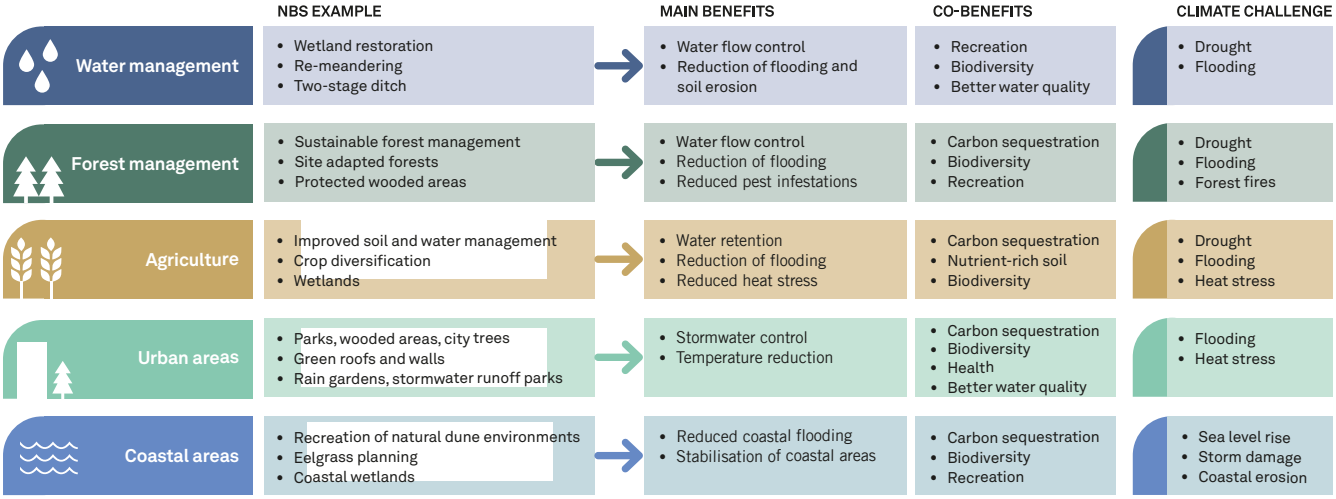
The goal of step 4 is to evaluate and estimate the impact of a solution. This will allow you to compare whether a nature-based solution or a combination of them should be chosen over a grey solution. The evaluation also helps you to select the solution that best responds to the challenges identified in step 1, as well as other objectives set for the project. The solution should be viewed as part of a whole, meaning part of an overall strategy for climate adaptation.

Based on the initial assessment of possible measures developed in step 3, in-depth analyses like cost-benefit analyses or multi-criteria analyses are done in this step in order to prioritise the different options.

[72] Thoni, 2017.

The analyses also help to determine whether a measure is justified from a socio-economic perspective and can be used for both nature-based and engineered measures. In order to compare engineered and nature-based solutions, it is vital to weigh and evaluate even the less visible benefits of a measure, which can result from, for example, ecosystem services as well as social values in the analyses. Below is a brief account of how to estimate the effects of nature-based solutions and the valuation of benefits related to such solutions, as well as links to supplementary documents.

Figure 5. Multifunctionality: The main benefits that nature-based solutions can offer to address climate challenges in different sectors, as well as the additional co-benefits that are created. The figure provides a simplified visualisation of the main benefits of addressing climate-related challenges and the potential co-benefits. Of course, the main benefit of an action like restoring a watercourse can also be to improve water quality.



Valuation and visibility of benefits

Since nature-based solutions are essentially multifunctional, they often provide more benefits – ecosystem services – than grey infrastructure solutions do (Figure 5).[73] Although well-planned nature-based solutions create a range of additional benefits in addition to their main purpose, it is not common for a nature-based solution to be chosen over an engineered solution usually because the additional benefits are not assigned an economic value. This is mainly because the ecosystem services are not commodities that can be traded in a market, despite the fact that valuation methods are available for capturing values that can be generated by ecosystem services.[74] When the values are not made visible, it becomes difficult to determine whether the nature-based solution is preferable in cost and benefit comparisons with other options. This disregard for values that can be attributed to the benefits of nature-based solutions means that the solution risks being undervalued compared to, for example, grey solutions. One example could be the lack of green space in highly dense urban areas.[75]

Valuing benefits generated by nature-based solutions is therefore not only about valuing the main benefit of the measure (for example, preventing a flood) but involves revealing all the structures, functions and processes in the ecosystems that shape the nature-based solution, which ultimately creates a benefit for society. Promoting the visibility of the many values created through nature-based solutions will enable us to make wiser decisions regarding our need for functioning ecosystems, not least for bolstering resilience in a changing climate.

Since nature-based solutions often provide a variety of ecosystem services (regulatory, supportive, supplying, cultural), a valuation of ecosystem services offers a way to promote the visibility and value of the diverse societal benefits they create (Figure 6). Values can be expressed in different ways: qualitatively, quantitatively or in monetary terms.

Values can be expressed in:

- Words (qualitative valuation)
- A physical unit, such as the amount of raw materials produced in a given period or the number of visits to a recreational area (quantitative valuation)
- Grades or scores (semi-quantitative valuation)
- Monetary units (monetary valuation).

[73] IUCN, Naturebased Solutions for Climate Change Adaptation & Disaster Risk Reduction

[74] Guide för värdering av ekosystemtjänster, naturvardsverket.se

[75] Review of Economic Valuation of Nature-based Solutions in Urban Areas, 2019

CASES

Valuing nature – making the invisible visible

Imagine that you regularly take a walk in your local park because it makes you feel good, both physically and mentally. The cost of going to the park is free, and you don't pay anything to get there or buy anything during your walk. From a market perspective, it looks like the park does not generate any economic value at all, while there is a municipal cost for maintaining the park. In reality, of course, the park has a substantial "invisible" value because a large number of people benefit from using or looking at the park.

What if the park disappears? If you can no longer exercise there, you might be more likely to get sick and have to stay home from work, bringing a cost to yourself and the community. Perhaps you just like to walk around the park and watch the changing seasons – there is value even in this kind of enjoyment, especially in lowering your stress levels in green surroundings. The properties around the park might be valued a bit higher on the housing market compared with other buildings. This economic benefit is reflected in individuals' valuation of the benefits of the park (perhaps the view or recreational services). All the values generated from the park's benefits together form the total economic value (TEV) of the park.

If we had enough data on increased productivity and lower healthcare costs for residents, we could evaluate the park's benefits through factors like better health through exercise and recreation. This is what we mean by making the invisible visible and valuing it in terms of the benefits a nature-based solution creates. In the Swedish EPA's ecosystem services guide, you will find descriptions of economic valuation methods that can capture total economic value.

There are several different approaches and methods for conducting an ecosystem service analysis and valuation of benefits related to ecosystem services. For guidance in the evaluation of ecosystem services, the Swedish EPA's "Guide to valuing ecosystem services" from 2015[76] can be useful. It in turn contains references to in-depth literature on economic valuation methods.

A monetary valuation[77] of all ecosystem services created through a nature-based solution can, however, be complex, resource-intensive and costly. This is because certain benefits can be difficult to derive or describe in monetary terms and also because it can be hard to find available indicators for the services to be measured. Furthermore, scientific data is often complex and might be inaccessible or simply not known.

It is therefore essential to provide clarity around the advantages of a proper monetary valuation of all the benefits resulting from ecosystem services in the project. In some cases, this can be key information that demonstrates the economic arguments for preferring a nature-based solution over a grey solution. In other cases, there might already be political positions and goals or a community commitment to pursuing green solutions and biodiversity. In such a case, the main focus can instead be on promoting visibility and describing the many hidden values created by the nature-based solution, qualitatively or quantitatively. Situations can also arise that demand putting a monetary value on the *specific benefit* of a solution (e.g. flood protection), while other benefits can be described quantitatively or qualitatively.

[76] Guide to valuing ecosystem services (diva-portal.org)

[77] In a cost-benefit analysis, for example, where all units must be expressed in monetary terms. Read more in, for example, the Swedish EPA's Samhällsekonomiska analyser av miljöprojekt – en vägledning (2014).

CASE – VÄRMDÖ MUNICIPALITY

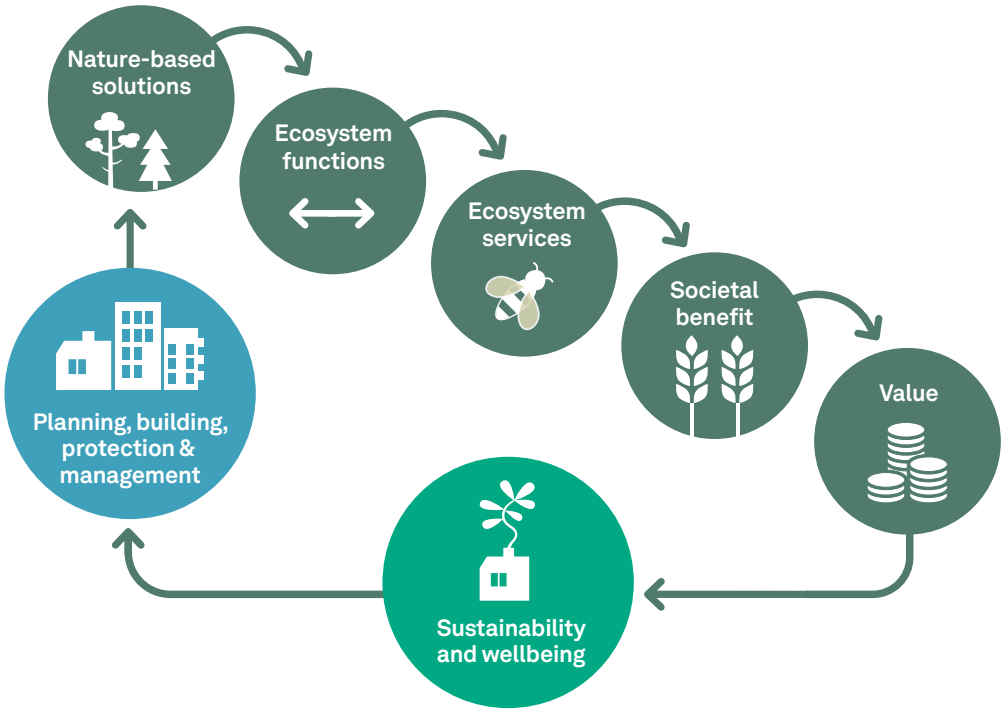
Measuring the overall benefit generated by a wetland

In a comprehensive analysis and valuation of the many benefits created by a nature-based solution, the solution can prove particularly cost-effective. One such example comes from a wetland and recreational area called Hemmesta Sjööäng, in Värmdö Municipality.[78] This municipality calculated the annual "revenue" by quantifying the economic value of the benefits created by Hemmesta Sjööäng through a monetary valuation of ecosystem services.[79]

In this case, the annual return of the benefits was estimated to exceed the cost of its implementation five times over. The municipality's problems with bicycle path flooding have thus been solved, while promoting biodiversity and outdoor recreation. Photo: Eva Stenvång Lindqvist.

[78] Hemmesta sjööäng – rekreation för fågel, fisk och människa, Final report 2014, varmdo.se
[79] Hemmesta sjoang, lansstyrelsen.se

Figure 6. From nature-based solution to societal benefit. The cascade model describes the connection between nature-based solutions and the economic benefits and values the solution can generate. When planning for nature-based solutions, promoting the visibility of the benefits and values created is a must for enabling this type of solution to be prioritised. The model is based on the cascade model for ecosystem services from the National Board of Housing, Building and Planning.[80]



In order to describe the nature-based solution and promote the visibility of the values it generates, we need to identify how it does this – as well as for whom and which values arise. One way to do this is by using an ecosystem service analysis because it allows us to take inventory of the different ecosystem services that the solution provides or is expected to generate, as well as what benefits ecosystem services can bring us. There are many different approaches, methods and levels of ambition when conducting an ecosystem service analysis. But overall, it should aim to map, analyse and visualise which ecosystem services exist or are expected to arise within a studied area[81] (in our case, a nature-based solution).

If a nature-based solution is intended to preserve an existing natural area because it provides protection of a coastal wetland against erosion, for example, then an ecosystem service analysis is particularly suitable. This is because the analysis identifies the ecosystem services already on the site and generates different benefits for the community. When the analysis instead aims to implement a nature-based solution, we want to try to analyse and illustrate which ecosystem services the planned measure can generate and which benefits can be provided.

[80] Ekosystemtjänster i plan och bygglagen, PBL kunskapsbanken, National Board of Housing, Building and Planning
[81] Ecosystem analysis, PBL kunskapsbanken, National Board of Housing, Building and Planning

The ecosystem service analysis also becomes a way to illustrate the ecosystem services that might be currently lacking at a site, which a planned nature-based solution could create or enhance. For example, there might be a lack of temperature regulators near a preschool, and a nature-based solution could provide ecosystem services that generate such benefits. Since the design of nature-based solutions should take place in multi-stakeholder dialogue, the stakeholders should ideally be involved in such an inventory in order to optimise the solution design for delivery of ecosystem services.

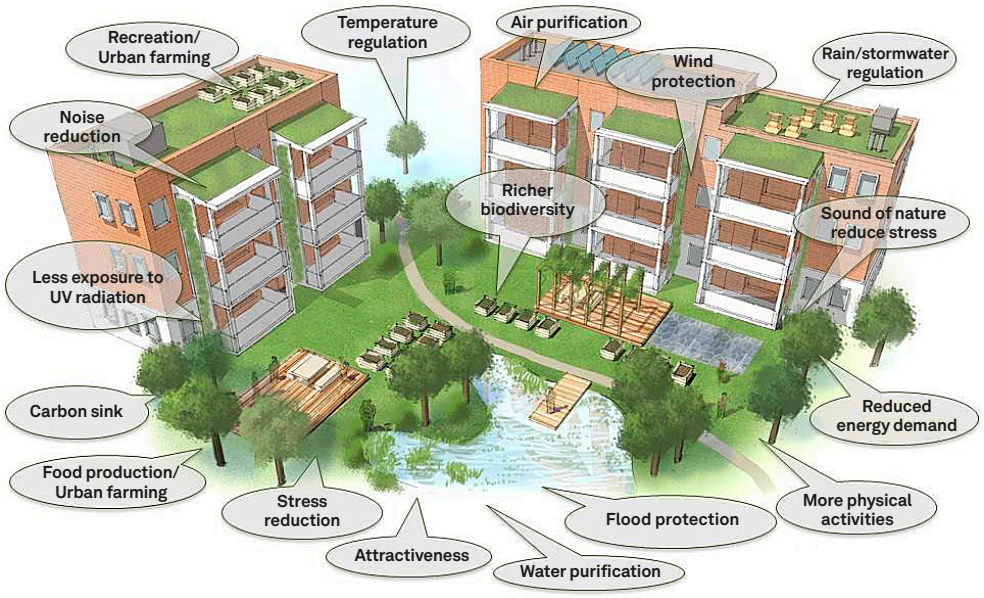
A good starting point is to use a completed list or documentation of potential ecosystem services (benefits) that a nature-based solution can provide. Appendix 2 of this report contains an example of such a supporting document, which reveals the benefits of different solutions based on the three sustainability dimensions: environmental, social and economic.

Next, a deeper analysis can be made of which ecosystem services exist or are expected to arise. An example of this is the Swedish EPA's listing of ecosystem services in its report "Ekosystemtjänstförteckning med inventering av data-underlag" or the list of ecosystem services types in the PBL Kunskapsbanken on the website of the National Board of Housing, Building and Planning.

TIPS

There are several useful documents to use that supports the work of carrying out ecosystem service analysis:

- National Board of Housing, Building and Planning: Ekosystemtjänster i den byggda miljön – vägledning och metod
- National Board of Housing, Building and Planning: ESTER: Verktyg för kartläggning av ekosystemtjänster
- c/o City: Ekosystemtjänster i stadsplaneringen – en vägledning
- Swedish Environmental Protection Agency: Vägledning om hur regionala handlingsplaner för grön infrastruktur kan bidra till att ekosystemtjänster och behov av klimatanpassning tillgodoses vid fysisk planering
- Swedish Environmental Protection Agency: Guide to valuing ecosystem services
- Swedish Environmental Protection Agency: Ekosystemtjänstförteckning med inventering av dataunderlag för kartläggning av ekosystemtjänster och grön infrastruktur



Illustrate the multifunctionality: By identifying and highlighting the many benefits that can be attributed to nature-based solutions and the ecosystem services they generate, we can put a value on "invisible" values that are otherwise at risk of being overlooked. The callouts in the figure show both ecosystem services and benefits created through nature-based solutions. Illustration: Magnus Petersson, Cloudberry. Source: C/O City.

After you do the actual mapping and analysis of the ecosystem services that can be derived from the nature-based solution, you will have revealed a large number of values and benefits that are generated or that we get automatically when you implement the solution. By clearly demonstrating the solution's multifunctionality, you also gain decision-making input that reveals the "invisible" benefits that otherwise risk being ignored in a valuation. This input will serve you well in the next step for prioritising the measures.

CASE HUDDINGE MUNICIPALITY

Report: Ecosystem service analysis of the Western Campus area, Flemingsberg, Huddinge Municipality

This report provides more information about the ecosystem service analysis conducted during planning of an urban development in the Flemingsberg district of Huddinge municipality. It contains a comprehensive description of the workflow of analysing, inventorying and mapping existing ecosystem services in the area and how they can be developed through the project.

▶ Read more here.

CASE Urban trees

I-Tree Sweden quantifies the importance of urban trees[82]

I-Tree Sweden is a three-year research project at the Swedish University of Agricultural Sciences that has figured out just how important urban trees are for air purification, carbon storage and stormwater detention in nine Swedish cities. The study calculates trees' ecosystem services in weight and volume and on the societal benefits that these ecosystem services provide, such as lower healthcare costs and lost work hours. The results of the study show that the trees in the nine Swedish cities provide socio-economic savings equivalent to slightly over 1.3 billion kronor by reducing air pollution and thus negative impacts on human health.

The report also quantifies the importance of urban trees for emission reductions and for stormwater detention and retention. The Swedish project was carried out in collaboration with arborist companies, churchyard management, housing companies and nine cities, from Luleå in the north to Malmö in the south. The purpose of the project and tool is to provide strategic support in urban planning concerning trees' ecosystem services. Both the tool and the report can be used as supporting documentation and an argument for clarifying the significance of urban trees for climate adaptation and sustainable urban planning. Photo: Anki Weibull

[82] i-Tree Sverige: för strategiskt arbete med träds ekosystemtjänster, slu.se

Prioritising the measures

In order to compare and prioritise possible solutions, any advantages and disadvantages of the projects must be clearly described. There are several options for evaluating and prioritising among the different options outlined in step 3. Two of the methods best suited for pursuing nature-based solutions are a cost-benefit analysis and a multi-criteria analysis.

Cost-benefit analysis

In a cost-benefit analysis[83], the project cost is compared with its welfare impacts, benefits and negative impacts; if the project's benefits exceed the costs, it is in theory viable to implement. Before implementing a nature-based solution, you might want to compare alternative solutions, in which case this analysis method provides a good foundation. In the cost-benefit analysis, the NbS project can be analysed against a reference situation ("doing nothing") or against an alternative grey solution with similar objectives as your nature-based solution. Usually, the consequences and benefits of the solution are valued in monetary terms in order to ensure comparability between several options. The analytical method therefore requires realistic estimates of the costs of each action over their entire life cycle, from investment through to use, maintenance and dismantling.[84] Understanding life cycle costs is essential for nature-based solutions, since many project models tend to focus solely on initial investment costs whereas NbS often delivers its full potential only after a certain period of time.

Multi-criteria analysis

Regardless of which method you decide to use, the analysis will likely have to include some form of multi-criteria analysis for comparing different solutions.[85] This analysis is often used as an alternative or complement to a cost-benefit analysis if not all benefits can be described in monetary terms, and helps you establish a basis for comparison between nature-based solutions and grey solutions. A multi-criteria analysis is a semi-quantitative method of analysis in which the outcome or function of a solution is weighted against several predetermined criteria.[86] The criteria that are set can be advantageously linked to the challenge at hand, such as the risk of flooding in a residential area. In the analysis, compliance with environmental, social and environmental criteria should be evaluated (for example, on a scale of 1–5; see the example below).

[83] CBA.
[84] ThinkNature, Nature-Based Solutions Handbook, thinknature.eu
[85] Samhällsekonomisk konsekvensanalys av miljöåtgärder, naturvardsverket.se
[86] ThinkNature, Nature-Based Solutions Handbook, thinknature.eu

The criteria should, of course, reflect how well a solution addresses the challenge, but it can also be directed towards other benefits besides the main purpose. An example might be the implementation of a stormwater runoff park to reduce the risk of flooding. So besides successfully managing the flood risk, perhaps you also want to promote biodiversity and create a recreational space. How well does the solution meet these requirements? In this way, the criteria help you to set the requirements while enabling you to compare nature-based solutions and grey solutions.

The weighted criteria are then used to rank action proposals. The valuation should be based on the expertise and views of the stakeholders. The criteria for fulfilment can have different weightings depending on the context and challenge you face, but usually work well when you choose the solution that best meets the criteria. The method also provides a handy tool for involving and consulting stakeholders like interest groups, residents and landowners. A robust process for a multi-criteria analysis among alternatives also allows for an iterative design process that ensures the optimal selection and design of a nature-based solution.

Keep the following factors in mind when performing the multi-criteria analysis:

- Analyse the costs, benefits, effects and synergies of different solutions – even of a zero option – in order to capture the advantages and disadvantages of the solution alternatives.
- Consider the sustainability and social benefits of the various solutions as well as resilience.
- Consider the long-term costs of care and maintenance and the benefits of evaluating different solutions – nature-based solutions can be more expensive in the short term but highly cost-effective in the long run.
- Also include an estimate of the costs that are avoided through risk management resulting from the action.

Clearly defined goals for the chosen solution help to set the right course, and provide a basis for follow-up and evaluation once the action is in place. Throughout the planning phase, the chosen solution and its design must be evaluated relative to the ecosystem services it will provide and the cost. This must also be followed up when the nature-based solution is in place. You can read more about this in step 6.

Table 3. Hypothetical example of weighting in a multi-criteria analysis between a grey and a nature-based solution (wetland). Freely interpreted from OECD 2019.[87] The score describes a value on a scale of 1–5.

Criteria	Grey infrastructure solution	Score	Nature-based solution	Points
Effect of flooding risk	Protective: Protects an area from flood damage by blocking water from seeping into a specific area.	3	Preventive: Reduces the likelihood of a flood occurring.	3
Time horizon for functionality	Immediate, grey infrastructure solutions provide protection right after they are implemented.	5	Delayed: NbS typically need time to provide the service because the landscape adjusts its morphology in response to the action. This process is dependent on physical processes that take over, causing a delay in achieving flood protection standards.	2
Cost of implementation	Low.	4	Medium/high.	3
Operation and maintenance	High.	1	Low operation and maintenance costs. NbS are often self-sufficient and self-preserving, reducing the need for maintenance.	4
Environmental footprint	Increased environmental footprint from using unsustainable materials and energy-intensive processes.	2	Low environmental footprint from using natural materials and processes.	5
Added value	Limited added value in providing ecosystem services. The protective nature of grey infrastructure has a potential negative side effect, since such solutions attract residents and economic investment to flood-prone areas (thereby increasing the risk of flooding).	1	Provides a wide range of ecosystem services (demonstrated by a completed ecosystem service analysis/highlighting of ecosystem services and values). Potential for delivery of ecosystem services over a long time span.	5

[87] OECD (2020)

READING TIPS

Examples of supporting documents for evaluating and prioritising nature-based solutions for climate adaptation and for performing socio-economic analyses of environmental projects.

- **Financial instruments for nature-based solutions to reduce risks of flooding and drought.** This report, by PE Teknik och Arkitektur, Lund University and Region Västra Götaland provides in-depth support and inspiration for valuing nature-based solutions and creating robust business models.
- **ThinkNature – Nature-Based Solutions Handbook.** Chapter 6, Financing & Business, provides valuable guidance on the financial arguments for pursuing nature-based solutions.
- **Nature-Based Solutions Initiative – Evidence platform – University of Oxford.** The website of the Nature-Based Solutions Initiative contains helpful information about the benefits nature-based solutions can bring in different landscapes, as well as an interactive heatmap for sorting the alternatives you want to evaluate and performing an impact assessment of the solution's function.
- **Swedish Environmental Protection Agency.** Samhällsekonomiska analyser av miljöprojekt – en vägledning.
- **Swedish Environmental Protection Agency.** Samhällsekonomisk konsekvensanalys av miljöåtgärder – Handbok med särskild tillämpning för vattenmiljö.
- **Swedish Environmental Protection Agency.** Ekonomisk värdering med scenariometoder – En vägledning som stöd för genomförande och upp-handling.
- **Swedish Transport Administration.** The agency's guidance, "Introduktion till samhällsekonomisk analys", provides valuable support in conducting a cost-benefit analysis for different projects.

Step 5. Implement the solution

After the fit-for-purpose solutions are selected, they must be designed and implemented. Depending on the type of solution, designing it and quickly implementing it can be easy. In other cases prerequisites must first be met, such as obtaining a permit, easement compensation, or inclusion in a detailed development plan or plan programme. Step 3 in this guide helps you prepare for any of these eventualities.

The goal of step 5 is to implement the solution based on the goal formulations, analyses and priorities developed in previous steps. Ensure continued stakeholder participation and review any exemptions or permits needed ahead of implementation. Ensure the continued consideration of biodiversity, participation and transparency and a sustainable resource use (see Safeguards in Table 1).

Environmental impact assessments and legal requirements

Some of the actions might need to undergo an environmental review or be submitted for consultation under applicable legislation, such as the Environmental Code or the Planning and Building Act. This is true regardless of whether the solution is a nature-based one or a grey solution. Time should be set aside for preparing such reviews and producing plans. Because these preparations take time, we encourage you to consider the need for any permitting procedure in advance (see step 3). If this has already been done, the process can have already begun. If not, this step might be necessary during step 5.

If the action will be carried out in parts of an area that are protected, then an exemption or authorisation must be applied for (see step 3). Nature reserve regulations might need to be reviewed and possibly revised to ensure the long-term management of a solution. In an area included in a detailed development plan, you might instead need permission according to the Planning and Building Act. Proposals might also need to be submitted for consultation. If transparency and participation have already been ensured throughout the process, which we encourage, then you already have a solid footing for consultation. Within reindeer husbandry, consultations have to take place at an early stage with the Sami Parliament and the relevant Sami communities.

An environmental impact assessment might also be required for the priority actions before implementation begins in order to gain an overall picture of the action's environmental impact and any risks to human health. Many of the analyses carried out in the previous steps can be used for central parts of the environmental impact assessment, whose details are regulated in the Environmental Code and Environmental Assessment Regulation. You can read more about environmental impact assessments of plans and programmes on the Swedish EPA's website.[88]

[88] Guidance on environmental impact assessments according to Chapter 6 of the Environmental Code, Swedish Environmental Protection Agency, naturvardsverket.se

Management plan

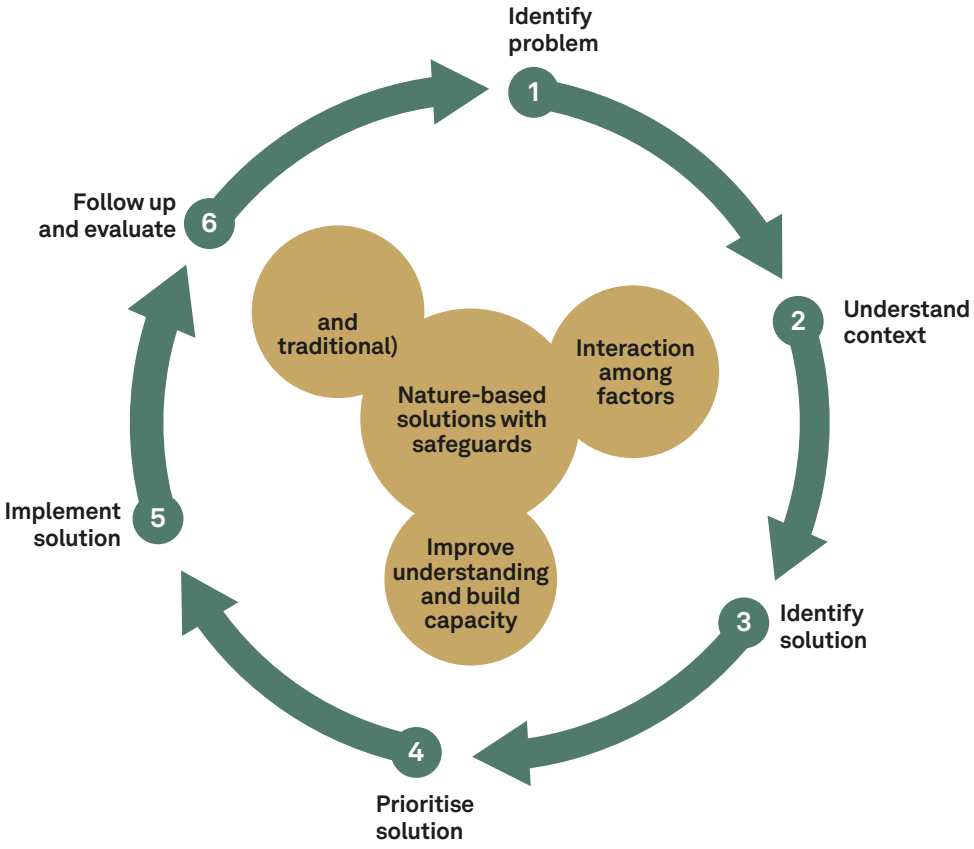
The need for upkeep and management of a nature-based solution, or even a grey solution for that matter, is something that should be clarified early on during planning. This is why it is mentioned back in step 3 ("List possible solutions"). Based on a basic assessment of management requirements over time, a more detailed management plan should be developed. Here, of course, the management and maintenance requirements must be specified, but it is also important to identify responsibility for future upkeep and maintenance work and its financing. A template for establishing a management plan for different types of green solutions in urban spaces has been developed by the project BiodiverCity.[89]

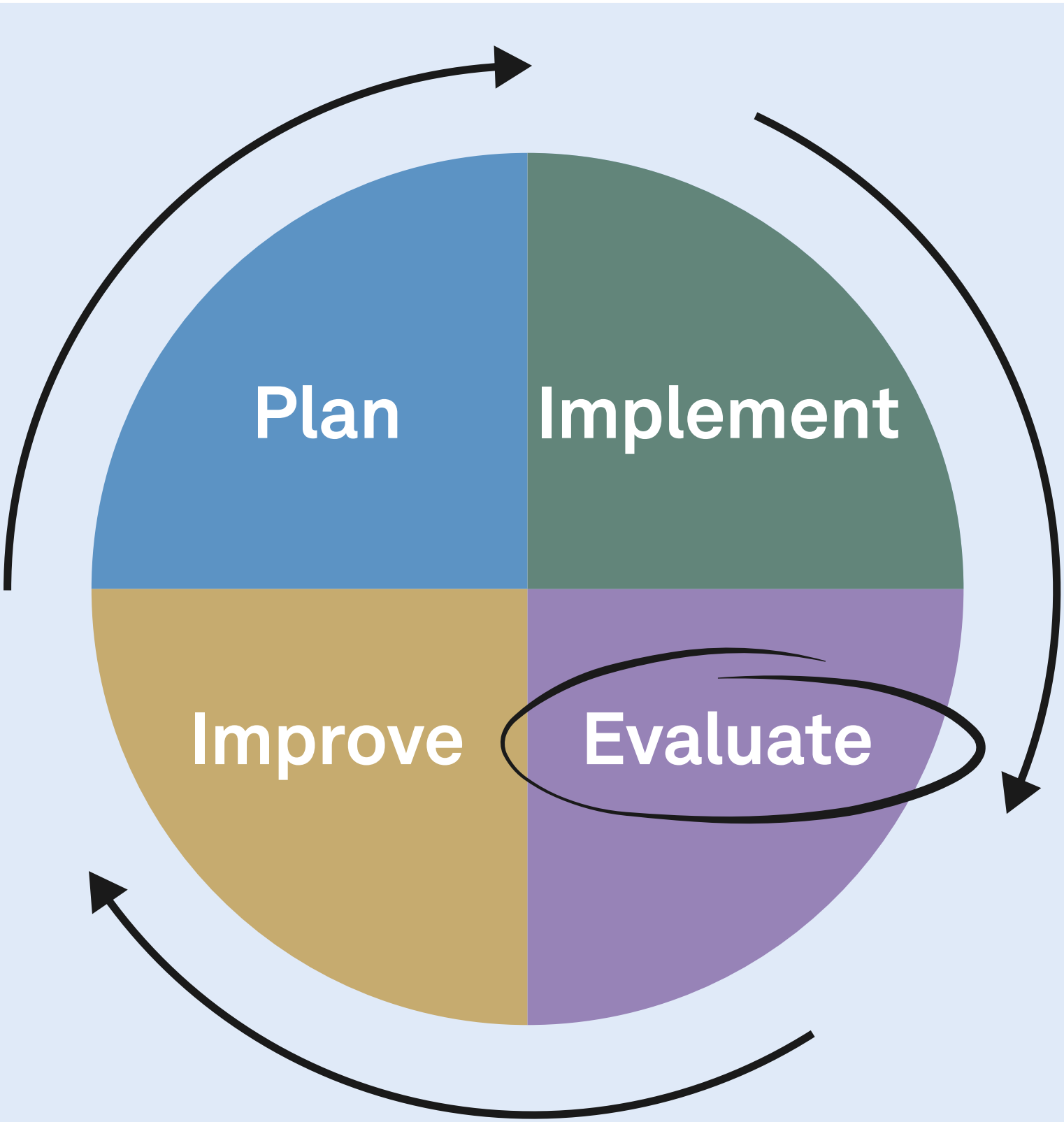
Throughout the process, it is vital to continue to ensure stakeholder engagement and to keep your focus on the impact of the action, on both the environment and the people concerned. Figure 7 presents a schematic sketch of the components in the guidance. The guidance is comprehensive and flexible in order to suit different contexts, starting points and challenges. The key is to clarify the effects of the solutions on the environment, biodiversity, and human health and welfare. Adaptive management[90] is an important part of the implementation, and involves a focus on learning and on following up and evaluating actions with regard to their impact relative to the set goals.

[89] Template for establishing a management plan for biodiverse areas, malmo.se

[90] Adaptive management means setting goals for what should be preserved or achieved, deciding on actions to achieve these goals, formulating a follow-up plan for the goals and actions, implementing the actions, and following up and adjusting the actions if the goals are not achieved. This takes place in an iterative process. The adaptive management model provides a systematic way to gain new knowledge throughout the process and to continuously adjust actions and goals based on the lessons learned.

Figure 7. Planning, analysing, implementing and evaluating nature-based solutions take place in an iterative process that ensures participation by building on knowledge, collaboration and increased understanding. See the list of protective measures in Table 1.




Plan
Implement
Improve
Evaluate

Step 6. Follow-up and evaluation

After a nature-based solution is implemented, its function – delivered benefit – and development over time must be followed up, analysed and evaluated to understand whether the action reached the set goals. This requires a careful selection of robust evaluation methods that enable monitoring of key indicators to demonstrate the project's success.

Follow-up and evaluation of nature-based solutions will be essential since there is currently a lack of knowledge and systematic evaluations of their full potential, especially for larger-scale solutions and their function over time. This risks opting out of nature-based solutions in favour of grey solutions that have a more well-established knowledge base.

Furthermore, there can be a delay in achieving the full effects and thus the benefits of nature-based solutions, such as with rain gardens or wetlands. The long-term effects and benefits of nature-based solutions can, however, be much greater than for grey solutions. Therefore, ongoing follow-up and evaluation of nature-based solutions is crucial. So, we need to ask ourselves questions like these: Did we get the benefits simulated in our initial analysis? If not yet, when will they be produced? Is some form of additional management or adjustment needed to achieve the desirable effects and benefits? A nature-based solution can, of course, also increase in value over time if it is one that takes time to fully establish itself, such as a wetland.

The goal of step 6 is to follow up on the measure's impact in order to enable an evaluation of the result. Follow-up and evaluation with respect to the central goal are important, as well as in relation to the other values or goals arising from a multifunctional solution. The timing and frequency of follow-up and evaluation depend on the solution, where and how it is implemented and what management requirements it has. It is necessary to develop a method or process for following up on the specific measures implemented and evaluating the effects of the nature-based solutions from a multifunctional perspective.

Key input for follow-up and evaluation can be found in the preparations from the previous steps – in the risk and vulnerability assessment, the identification of the challenge and the desired situation, and in the formulation of goals. For example, follow-up should be taken into account when considering possible measures in step 3: Are there any indicators to use? Are there ongoing follow-up or monitoring systems in place that can be used or developed in order to include the intended solution? Also, there might be traditional local knowledge that exists but is not documented and is thus hard to access.

It is therefore important to identify such knowledge early on in the project planning so that the relevant parameters for follow-up are included. Since multifunctionality is a hallmark of nature-based solutions, follow-up also needs to be. The technical, biological, social and health impacts all need to be followed up, as do the costs of things like upkeep and maintenance. The choice of method for monitoring and evaluating a specific NbS project depends on a variety of factors, such as project objectives, project size or scale, expected impact and benefit, and available resources for evaluation. Since the method chosen for follow-up and evaluation depends on

the specific nature of each project, there is no universal model. Below, however, are several criteria that the chosen method should be able to meet and that recur in most NbS projects:[91]

- **Long-term evaluation at multiple scales.** The scale of implementation and the effects over time and space should be evaluated. The effects of nature-based solutions vary, from micro (for example, street level) to macro (regional to national level). Furthermore, nature-based solutions are based on dynamic processes in living ecosystems that evolve over time. This means that the function of a nature-based solution can be affected by a number of change factors, ranging from land use to climate change. In addition, a solution might first reach its full potential (effect) only after a long period of time.
- **Secure access to output data/status.** In an evaluation of how well a nature-based solution works, you ideally want to be able to compare the status before and after implementation. To allow for such a comparative analysis, the availability of reliable basic data about the situation must be secured before the solution is implemented. Long time series of data become essential for comparing examples of temperature regulation in cities or erosion effects.
- **Potential to implement, compare and copy.** Try to choose a monitoring model that is simple and does not require too much specialised knowledge. Data and collection methods should also be standardised as much as possible. This makes it easy to replicate and reuse the method for several different case studies or projects.
- **Quality and accuracy.** The method used should be of a high research quality and weigh all processes and interactions linked to the parameters being evaluated. The method should enable both quantitative and qualitative follow-up, reflect the accuracy of the results and be scientifically proven. At the same time, traditional local knowledge must also be included.
- **Cost-effectiveness.** Monitoring the efficiency of the project can be costly. Therefore, a simple and cost-effective monitoring system should be developed for the nature-based solution.

[91] ThinkNature, Nature-Based Solutions Handbook, thinknature.eu

The results collected from monitoring the nature-based solution should, of course, be compared against the goals set for the project. Such an evaluation will provide a valuable picture of whether the solution is working and delivering the services it was intended to.

Since most nature-based solutions are essentially based on dynamic and complex functions that make up an ecosystem, this also implies a measure of uncertainty. This can negatively affect the result or attainment of all the goals. In such a case, the information collected through the monitoring is useful for returning to the position taken in previous steps in order to investigate whether adjustments can be made to meet al. the criteria set. A simple example is how a wetland is implemented in order to bind nutrients. If the wetland does not meet this criterion, the choice of vegetation might need to be adjusted or the flow of water slowed. In this way, the follow-up and evaluation of the measure become necessary for enabling modifications and adaptations of the solution as needed over time. This iterative process is a form of adaptive management.

CASE Helsingborg Municipality

Monitoring and follow-up of nature-based solutions in the Råån catchment area

Through its participation in the Interreg project Building With Nature, the County Administrative Board of Scania has investigated the impact of water conservation measures including dams, wetlands and two-stage ditches on regulating water flows and reducing flood risks in the Råån catchment area Helsingborg Municipality. The aim is to re-create the conditions that existed before large-scale drainage took place in southern Sweden.

In a comparative analysis of different flood scenarios, the project evaluated flow loads for scenarios with and without the installation of water conservation measures. The scenarios revealed that water conservation measures have an overwhelmingly positive flood mitigation effect. Dams and wetlands both limit spatial distribution and maximum flows, while two-stage ditches have a flood-attenuation effect if they are simultaneously combined with regulated discharge. This type of modelling has succeeded in evaluating the project's set objectives and criteria, even if the estimated maximum flow has not yet been reached.

▶ Read more about the project.

4

Nature-based solutions in different landscapes

This chapter intends to provide inspiration and knowledge of what a nature-based solution can entail, with examples of implemented measures. A nature-based solution can be anything from small and locally operated to highly extensive, spanning several different landscape types or municipal boundaries. In this section we present examples of nature-based solutions in different types of landscapes. We first discuss wetlands, since flooding is a climate-related problem and wetlands show great potential to regulate water in the landscape. Of course, wetlands can also be found in the other landscapes presented. After wetlands, we present examples of nature-based solutions in the built environment. Here, of course, a climate adaptation solution can be situated in a forest or in the countryside outside city limits throughout a catchment area. Finally, we present examples of nature-based solutions in forests, in the agricultural landscape and in coastal environments.

READING TIPS

Several handbooks and manuals containing specific examples of nature-based solutions are available that can make a valuable companion to this section:

- **Engineering With Nature – An Atlas**
- **Oppla – EU knowledge bank for nature-based solutions**
- **Naturevation – Urban Nature**
- **Atlas ThinkNature Handbook**
- **Klimatanpassa nordiska städer med grön infrastruktur – SMHI**

Wetlands

Although Sweden has been a wetland-rich country, nearly a quarter of its original wetlands have disappeared in the last century. The largest share has been lost in the plains of southern Sweden: in Scania and Mälardalen, only about one-tenth of the original wetland areas remain.[92] Wetlands have disappeared completely because of drainage or sinking water levels in lakes, the straightening and clearing of water-courses, and the construction of dams and power plants. Of the remaining wetlands, 80 % are affected by human interventions like drainage and peat extraction.[93] Many of them today are also surrounded by developed land, which makes them more vulnerable and sensitive to change. As urban areas expand and new infrastructure is built, the risk looms that even more wetlands will vanish.

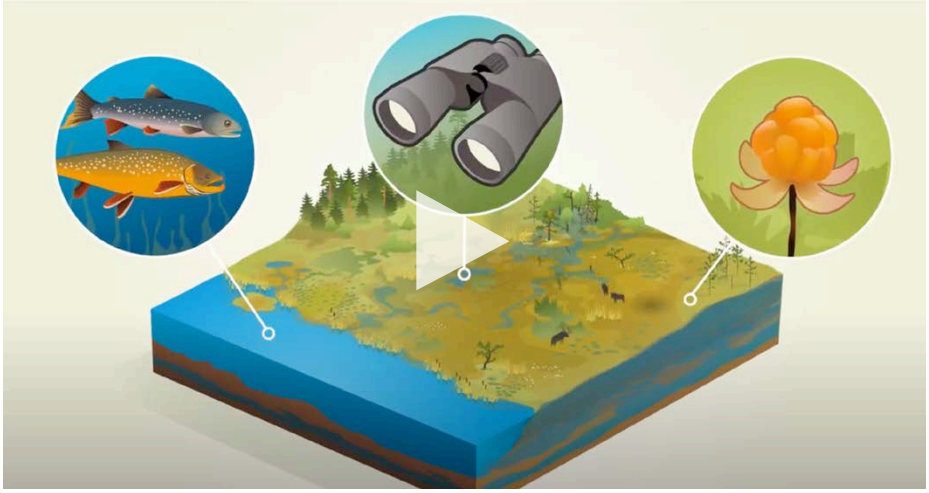
WETLAND ECOSYSTEM SERVICES

Just like other ecosystems, wetlands can provide a variety of ecosystem services, as summarised in a major international study on ecosystem values (Table 4).[94] Unlike other ecosystems, wetlands play a special role in the water cycle by receiving, storing and releasing water over time, providing water and regulating water flows.[95] There are many studies demonstrating that wetlands reduce the magnitude and frequency of flooding.[96] Yet studies exist showing that wetlands instead increase flooding, though this happens when wetlands are planned, sited, designed and managed without consideration for the design and topography of the landscape and the soil characteristics at the site.[97]

[92] Våtmark, naturvardsverket.se
[93] Argument för mer ekosystemtjänster, naturvardsverket.se
[94] The Economics of Ecosystems and Biodiversity for Water and Wetlands, 2013, teebweb.org
[95] Global Wetland Outlook, ramsar.org
[96] Acreman et al. 2003. Ferrari et al. 1999. Wu and Johnston, 2008.
[97] Acreman and Holden, 2013.

VIDEO TIPS

This short video describes the features of wetlands, such as evening out water flows, binding carbon, purifying water and offering space for biodiversity and recreation. The video was developed during the work on Green Infrastructure.[98]



Wetlands can also create opportunities for recreation wherever they are implemented. For example, the regeneration and restoration of wetlands can provide spaces for recreation and outdoor activities, as well as promote human interaction and nature tourism. An example is the biosphere reserve Kristianstad Vattenrike in Kristianstad Municipality.[99]

[98] Grön infrastruktur, naturvardsverket.se
[99] Biosfärområde Kristianstads Vattenrike – Bra för natur och människa

Table 4. Wetland ecosystem services and examples of valuation studies. The table is taken from "The Economics of Ecosystems and Biodiversity for Water and Wetlands".[100]

Ecosystem services	Structures & functions	Examples of valuation study
Coastal protection	Attenuates waves, buffers winds	Badola and Hussein (2005), Barbier (2007), Costanza et al. (2008), Das and Vincent (2009), Bayas et al. (2011)
Erosion control	Provides sediment stabilisation and soil retention	Sathirathai and Barbier (2001)
Flood protection	Water flow regulation and control	Brouwer and van Elk (2004)
Water supply	Groundwater recharge/discharge	Acharya and Barbier (2000, 2002), Smith and Crowder (2011)
Water purification	Provides nutrient and pollution uptake, as well as retention, particle deposition	Byström (2000) Yang et al. (2008) Jenkins et al. (2010)
Carbon sequestration	Generates biogeochemical activity sedimentation, biological productivity	Jenkins et al. (2010) Sikamäki et al. (2012)
Maintenance of temperature, precipitation	Climate regulation and stabilisation	
Raw materials and food	Generates biological productivity and diversity	Sathirathai and Barbier (2001), Islam and Braden (2006)
Maintains fishing, hunting and foraging activities	Provides suitable reproductive habitat and nursery grounds, sheltered living space	Johnston et al. (2002), Barbier (2007) Smith (2007) Aburto-Oropeza et al. (2008), Sanchirico and Mumby (2009)
Tourism, recreation, education and research	Provides unique and aesthetic landscape, suitable habitat for diverse fauna and flora	Hammitt et al. (2001), Johnston et al. (2002) Carlsson et al. (2003), Othman et al. (2004) Brouwer and Bateman (2005), Birol et al. (2006) Birol and Cox (2007), Do and Bennet (2008), Jenkins et al. (2010)
Culture, spiritual and religious benefits, bequest values	Provides unique and aesthetic landscape of cultural, historic or spiritual meaning	Kwak et al. (2007)

[100] Russi et al. 2013.

A compilation of several research studies shows that wetlands on average reduce both the extent and the frequency of floods but that it is difficult to predict exactly by how much, especially if the site-specific conditions are not taken into account.[101] This means that it is important to understand specific site conditions, including conditions in the surroundings and the catchment area, before choosing a wetland as a nature-based solution. By following the steps in this guide, you can help secure the social, environmental and economic conditions, both locally and on a larger scale, for all nature-based solutions.

Wetlands and climate change

The potential and ability of wetlands to detain water in the landscape is compelling from a climate adaptation perspective, since the challenges of either too much or too little water grow with a changing climate. Because today's wetlands are heavily influenced by human activity and actions, several of the basic functions and ecosystem services that a wetland provides have been adversely affected, including their water-conservation properties. Straightened rivers and fewer wetlands mean that less water is retained in the system, and that heavy rains or heavy snowmelt cause flooding. These, in turn, damage arable land, infrastructure and buildings and pose risks to human health.

The fact that the water flows faster towards lakes and seas also causes an increased risk of erosion, as well as avalanches and landslides when soil is washed away. Without natural waterways, groundwater supply and water storage in the landscape also decreases, which can exacerbate water scarcity during periods of drought. To reduce the risk of adverse effects from climate change, degraded functions in watercourses, lakes and wetlands must often be restored.

WETLANDS IN SPACE AND TIME

When pursuing nature-based solutions, conditions in the surrounding landscape should always be considered. This is especially true when focusing on water in the landscape, where the entire catchment area can be relevant to consider. A wetland is rarely found in isolation; usually, water moves through the landscape via different types of wetlands. Several different nature-based solutions might be needed to promote the functionality of water flow through the landscape, sometimes in combination with grey solutions.

The wetlands' ability to produce useful ecosystem services over a significant period of time is also important to remember. A constructed wetland can also evolve over time, so a long time horizon should be adopted in order to reasonably compare the benefits of a new wetland versus any engineered solution.[102]

[101] Kadykalo and Findlay, 2016
[102] Argument för mer ekosystemtjänster, naturvardsverket.se

THE RIGHT WETLAND IN THE RIGHT PLACE

A relatively simple nature-based solution when it comes to wetlands is preserving the ones that exist. If the wetland is affected by earlier measures, extensive restoration measures can be taken (see the example in Figure 8). Another solution can be to install new wetlands. This must be done in a thoughtful way to ensure that the effect of the wetland corresponds to the goal of the measure. By finding the right location for the wetland, investing in preservation or restoration of the hydrology of existing wetlands, creating new wetlands and providing scope for temporary floodwater storage areas, there is a greater possibility of achieving the goals for the wetland. More information and guidance on wetlands is available on the Swedish EPA's website, including factsheets on multifunctional wetlands.[103]

CASE Sollentuna and Upplands Väsby

Re-meandering of a river

Edsån, located in Sollentuna and Upplands Väsby municipalities, is a river that flows through urban areas and farmland. The river previously had a completely straightened course with steep and somewhat erosion-sensitive ridge slopes that could be likened to a deep, large ditch. During high flows, parts of the low-lying arable land northeast of the river became flooded. But in 2013–2015, the river was restored and returned to its original somewhat meandering shape to slow the water's speed through the landscape and thus improve water quality and promote biodiversity. This also reduced erosion.[104]

Nowadays, over a course of about 600 metres, the river winds its way along a course that is roughly 1,200 metres long. The nature in and around the river has become more varied and rich, supporting water purification and biodiversity. Accessibility to the area has also been improved.[105] Source: Google Maps.

[103] Våtmark, naturvardsverket.se
[104] (2) Edsån bygg om för öka vattenkvalite och biologisk mångfald – YouTube
[105] lagesrapportedsanmaj2018.pdf, sollentuna.se

THE RIGHT WETLAND IN THE RIGHT PLACE

To best leverage a wetland's flow regulation properties or balancing effect, both local and regional planning for climate adaptation are needed. Both the individual land or property owner and society at large have much to gain from ecosystem-based solutions for water flow regulation. Remaining wetlands and watercourses with natural flows help provide protection against floods that can cause huge economic losses, demonstrating that conservation usually pays off. The following measures are central to the installation, conservation and restoration of wetlands.

Prioritising the preservation of existing well-placed wetlands

Wetlands that already exist are in their current locations because of site-specific conditions. They are already well sited and provide several ecosystem services. Preserving existing wetlands is often most cost-effective, or restoring former wetlands where natural flows already exist.

Restoration measures are ideal for wetlands that already serve as natural retention basins. Their location in the catchment area is crucial for flow detention.[106] Wetlands high up in catchment areas can have a flow-attenuating effect and reduce the risk of flooding in lower-lying areas. The solution to a local flood problem can thus be located far away from the problem area.

Restore wetland hydrology

Hydrological restoration of wetlands can entail closing ditches and increasing the water storage capacity of the catchment area. Another method is the re-meandering of straightened watercourses, a measure that increases the water's residence time and capacity for storage in the landscape. Re-creating a floodplain – low-lying ground formed by sediments adjacent to a watercourse and subject to flooding – far up in a catchment area creates a more even flow downstream. Porous soil layers are found along many watercourses that can balance water flow and recharge groundwater aquifers if they are allowed to be flooded.

Construct wetlands

Constructed wetlands can boost the landscape's capability to conserve water. During periods of drought, it can allow for a certain amount of water abstraction and relieve the usual groundwater reservoirs.

Make room for temporary floodwater areas

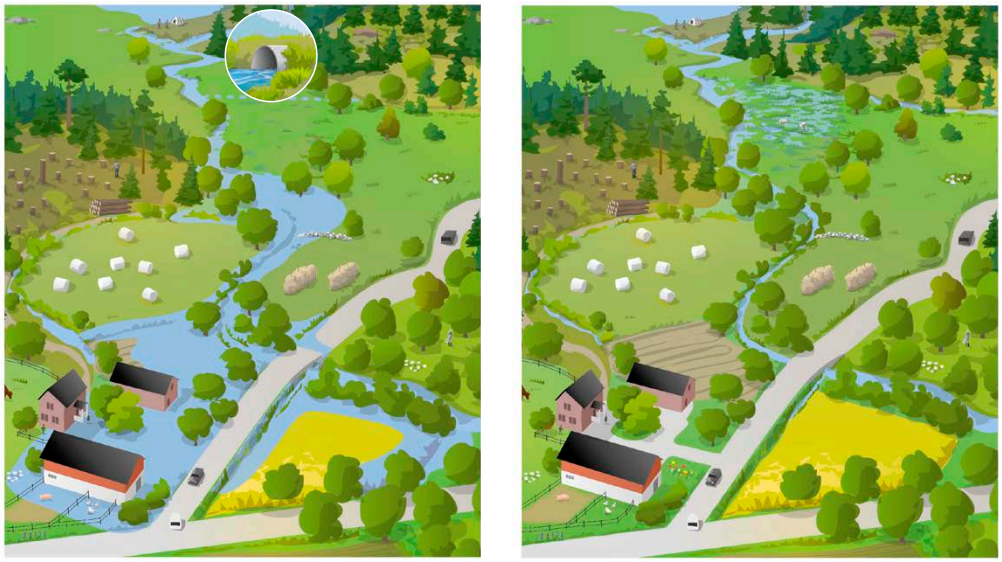
In the agricultural landscape, afforested flood zones adjacent to watercourses can have an attenuating effect on elevated water flows. Forested land captures 10–40 times more rainwater than ordinary farmland. Along many straightened, smaller watercourses, two-stage ditches can have a flow-attenuating effect. Wide flood zones are created in these ditches, which increases the buffer capacity of the watercourses while taking up a relatively small area.

[106] Multifunktionella våtmarker 3: Minskad översvämningsrisk, naturvardsverket.se

Examples of nature-based solutions for wetlands

On the island of Värmdö outside Stockholm lies Hemmesta Sjöäng, an area prone to recurring flooding of pedestrian and bike paths. Two options were available to fix this problem: either raise the bike path and drain the area, or restore the wetland and re-create its function of regulating water flows. Both options were estimated to cost the same. The nature-based action of restoring the wetland was chosen and implemented with great success, proving that many value adds and multiple benefits were gained for free. Since 2014, the wetland is restored and working as intended. The area has not yet seen any flooding, biodiversity has improved, and the area can be used for outdoor recreation, sportfishing and instructing schoolchildren about nature.[107]

Figure 8. At left: A drained, culverted wetland (circled) increases runoff downstream (bottom of image), with flooding of buildings and roads as a result. At right: The flow-attenuating effect of the wetland upstream (top of image) helps to keep the water in the landscape during high flows.



[107] Hemmesta sjöäng, Värmdö Municipality, varmdo.se

Getinge offers another example of how to combine engineered solutions with nature-based ones.[108] The Suseån river flows through the community and used to overflow periodically, causing water damage to homes and forcing local businesses and roads to be blocked off. The solution to the problem was threefold: two protective barriers were built, one on each side of the river, and wetlands were installed between the embankments. In addition to their function as a flood barrier, the wetlands also help to remove nutrients from the water and benefit biodiversity. The third part of the solution was to make the area more accessible for recreation by providing walking and exercise paths, something that Getinge's residents welcomed.

Another example of wetland restoration can be found in Scania around Höje Å, a watercourse that flows through the municipalities of Lund, Lomma and Staffanstorp. The three municipalities had started a collaborative project way back in 1991 with the aim of fighting eutrophication, reducing the risk of flooding and promoting biodiversity and recreation.[109] The follow-up has shown good results in terms of the eutrophication problem. Yet the flooding challenge still remains, especially for Lomma Municipality, which is most vulnerable when the river overflows. In its master plan, Lomma Municipality stresses the importance of continuing to work on the issue in collaboration with the other municipalities and of implementing solutions higher up in the catchment area.[110]

[108] Våtmark, översvämningsskydd och rekreation kombineras i Getinge, SMHI
[109] Kommunal samverkan kring vattenproblem, fördjupning, SMHI
[110] 2020 master plan, Lomma Municipality

CASE Lilla Rickeby

The embankment that became a wetland

In Lilla Rickeby outside Arlanda, a cultivated grassland area was converted into a wetland. The location of the wetland high up in the catchment area makes it function as an effective flow equaliser that helps to reduce erosion on the slopes of the ditch downstream.

The wetland therefore helps to reduce nutrient loss from the somewhat eroded organic soil in the area. In addition, it contributes to rich bird life in the area.[111]

Initially the plan was to create a wetland of about 2 hectares, but thanks to neighbourhood outreach it turned into 10 hectares. Since the wetland would affect nearby drainage companies, permission from an environmental court was needed. The permit application and a technical description were created, as well as an environmental impact assessment. Photo: Jonas Andersson

[111] Lilla Rickeby våtmark, Våtmarksguiden, vatmarksguiden.se

Urban areas

Today, nearly 87 % of Sweden's population lives in urban areas,[112] on a surface that makes up 1.5 % of the country as a whole – and projections show how metropolitan regions and major cities continue to grow.[113] Our urban environments are largely planned based on the prevailing climate, which makes many of them particularly vulnerable to the effects of a changing climate, such as floods from watercourses, cloudbursts[114] or prolonged heat waves.[115] Coastal communities are also at risk of extensive damage from flooding, avalanches, landslides and erosion as a result of elevated sea levels, in the form of both temporary storm surges and permanent sea level rise. To address the challenges that a changing climate poses for our urban areas, adaptation measures are necessary in both the existing environment and when planning new builds.

Effects of a changing climate in cities

Temperatures in the city

Temperatures in cities are generally higher than in surrounding areas. This is called the heat island effect, and is caused by the inability of impervious and often dark surfaces in cities, such as buildings and road pavement, to reflect heat to the same extent as land with vegetation does (see Figure 9). At night the stored heat is released, raising the air temperature. The waste heat from buildings, traffic and people, as well as a lack of urban greenery (which causes a lack of evapotranspiration) also contribute to elevated temperatures in urban areas. All in all, these factors contribute to city temperatures that are higher than in surrounding areas, and urban environments create their own microclimates.[116]

[112] An urban area is defined here as contiguous settlements with at least 200 inhabitants.

[113] Urbanisation, National Board of Housing, Building and Planning, 8,6 miljoner bor i Sveriges tätorter, scb.se

[114] SMHI defines a cloudburst as at least 50 mm of precipitation per hour or at least 1 mm in one minute.

[115] SMHI defines a heat wave as a period of at least three consecutive days with a maximum daily temperature of at least 26 degrees Celsius.

[116] Bevarande och hållbart nyttjande av biologisk mångfald i ett förändrat klimat, government report, naturvardsverket.se.

TIPS

The website of the Swedish Meteorological and Hydrological Institute SMHI contains valuable information about managing elevated temperatures and heat waves in urban environments through good urban planning, developed through the research project "Hazard support". A short video summarising how to plan for a warmer climate is also available.

The urban heat island effect is particularly evident during longer periods of high temperatures, and can intensify and prolong heat waves. On top of this are the effects of climate change, with an elevated global average temperature and the risk of more intense and more frequent heat waves. This combination of increased temperatures puts human health and well-being at risk.[117] For example, persistent periods of heat during the summer can adversely affect health and drive up mortality rates. Children, the elderly and the chronically ill are particularly vulnerable.[118] Studies also show that residents of cities in northern Europe have a lower tolerance for high temperatures compared with residents of southern European cities with higher average temperatures, making northern European cities more vulnerable.[119]

[117] Att hantera hälsoeffekter Vägledning till handlingsplaner, folkhalsomyndigheten.se
[118] Public Health Agency of Sweden, 2015.
[119] Health and Global Environmental Change SERIES, No. 2 Heatwaves: risks and responses , who.int.

Figure 9. The image illustrates an urban heat-island effect, where the city has a higher temperature than its surrounding landscape. Source: SMHI.

Water in the city

Cloudbursts[120] (for example, 10-year and 100-year rains[121]) that pummel delimited urban areas without much advance warning are expected to become both more intense and more common because of climate change.[122] But the problem is already making itself felt: several urban areas in Sweden have been impacted by extensive and costly floods as a result of cloudbursts in recent years.[123] Urban environments are particularly vulnerable because of the high proportion of impervious surfaces – streets paved with asphalt or paving stones, parking lots, buildings – where rainwater is unable to filter down into the ground and instead flows on top of the surface.

During cloudbursts, the water pipe network and ditches often lack the capacity to manage stormwater runoff, since they are usually only dimensioned to manage typical amounts of rain. When capacity is exceeded and the pipe network is overloaded, the risk of both flooding and discharge increases.[124] Studies show, for example, that in urban environments with 50–90 % impervious surfaces, 40–80 % of rainwater becomes surface runoff, compared to a forest landscape where only about 13 % disappears as surface runoff.[125]

Furthermore, peak flows in urban watercourses can be 30–100 % higher than in comparable rural environments (see Figure 10). The proportion of impervious surfaces usually increases in tandem with development and densification, which in turn puts further pressure on stormwater management in urban areas. Yet it can be both costly and complicated to expand the current stormwater management infrastructure, both above and below ground.[126]

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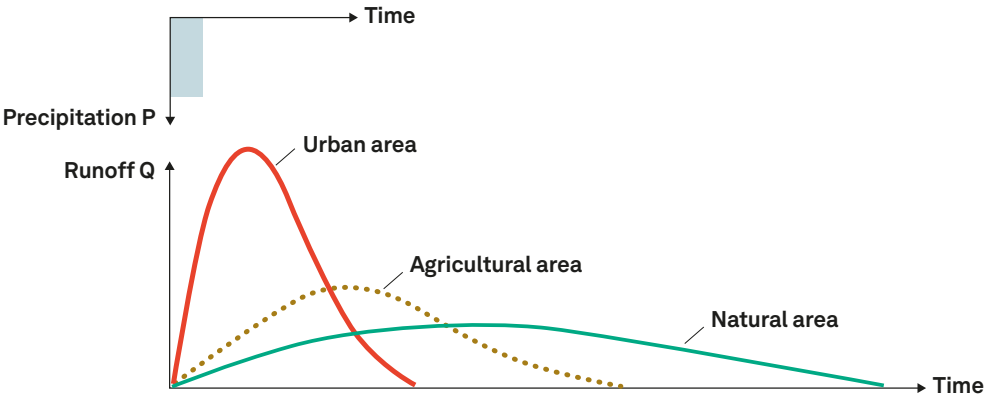
[120] According to SMHI
[121] Cloudbursts that are expected to fall with a return period of 10 or 100 years
[122] Extreme short-term precipitation in climate projections for Sweden according to SMHI
[123] Cloudbursts in 2014 in many locations including Malmö according to SMHI
[124] Discharge is when untreated sewage is released into the nearest surface waters
[125] Pataki et al. 2011
[126] Lund University, CEC Synthesis No. 4. Ekosystembaserad klimatanpassning – en kunskapsöversyn, 2017, lu.se

Figure 10. Runoff processes in different areas. Illustration: Swedish Water & Wastewater Association.[127]



Rising sea levels and coastal settlements

Sea levels are rising as global average temperatures increase. This is due both to thermal expansion[128] and melting of land-based ice sheets and glaciers. Average global sea levels rose 0.16 metres from 1902 to 2015 and are expected to rise about 0.3–1.1 metres by the end of the century, according to the IPCC's lowest and highest emission scenarios.[129] At the same time, the IPCC underscores considerable uncertainty, with a mean sea level rise of 2 metres by 2100 not being ruled out. Regardless of the climate scenario we start out with, sea levels are expected to continue to rise for hundreds of years beyond 2100 and then remain elevated for thousands of years.[130]

Rising sea levels increase the vulnerability to both flooding and erosion damage, such as from avalanches and landslides, as well as problems involving elevated groundwater levels and salt ingress. For Sweden's part, this naturally has an impact on planning and development along the country's coasts.

Since the post-glacial rebound in northern Sweden is still greater than the sea level rise, rising sea levels are of major importance mainly in southern and central Sweden. In the longer term, however, sea level rise can also affect the coasts of northern Sweden. The uncertainties in the assessment of future sea levels are great, which makes them difficult – yet essential – to consider when planning for coastal area development.[131]

The section on coasts below discusses nature-based erosion and flood protection in more detail.

[127] Hållbar dag och dränvattenhantering – råd vid planering och utförande, Vattenbokhandeln, svensktvatten.se

[128] Thermal expansion, or heat expansion, is the increase in the size (e.g. volume) of a body, in this case, the sea, due to an increase in its temperature.

[129] The Ocean and Cryosphere in a Changing Climate, DOI 10.1017/9781009157964, ipcc.ch

[130] Havsnivåhöjning efter 2100, SMHI

[131] Klimataspekter och tidsperspektiv, PBL kunskapsbanken, National Board of Housing, Building and Planning

Nature-based solutions in built-up environments

With the right conditions and planning, nature-based solutions in urban environments have the potential to meet most of the climate-related challenges described above (Figure 11).[132] Urban vegetation, such as parks or urban forest areas, can help improve microclimates by reducing solar radiation, providing shade, regulating air temperatures and reducing the urban heat island effect. For example, calculations of the cooling effect of greenery in a major London park area reveal that temperatures could be as much as 4 degrees lower in the park, and that its cooling effect extended up to 400 metres from the park.[133]

Trees and other types of vegetation in cities also play a major role in managing downpours and peak flows during cloudbursts, by absorbing, storing, detaining and evaporating water and by making the soil more porous and infiltration-friendly. For example, a study from Manchester in the UK shows that trees reduce runoff flow on surfaces by slightly more than 60 % compared with asphalt surfaces, and that grassy surfaces retain almost all water.[134] Other nature-based solutions, such as bio-dykes, green walls and green roofs, detention ponds, constructed wetlands, rain beds, rain gardens and permeable surfaces can also help to detain and minimise surface runoff during heavy rainfall, thereby reducing the risk of flooding in urban areas. Nature-based solutions in the urban environment are not always capable of managing all surface runoff during cloudbursts, but they can be important complements and offload existing stormwater systems.

Nature-based solutions in urban areas can create several other benefits in addition to temperature and stormwater management, not least for human health and well-being. Studies find, for example, that when optimising the selection and location of vegetation in order to maximise deposition of air pollution on the foliage, urban greenery can help improve air quality.[135] Urban vegetation also often helps to mitigate noise, which can help create better acoustic environments.[136]

[132] Naturens betydelse för klimatanpassning, PBL kunskapsbanken, National Board of Housing, Building and Planning
[133] Doick et al. 2014.
[134] Armson et al. 2013
[135] Janhäll, 2015. Kabish et al. 2017
[136] Vegetation och ljudmiljö, J. Henriksson, slu.se

Figure 11. Examples of nature-based solutions in urban environments: green roofs, urban greenery, urban trees, rain gardens, swales, stormwater ponds and permeable surfaces.

Parks and other forms of green spaces can also bolster people's mental and physical well-being through relaxation, stress reduction, social interaction and as an opportunity for physical activity and recreation.[137] Studies show, for example, that five minutes of walking in a forest can lower heart rates and blood pressure, and help to improve the immune system and concentration ability.[138] Urbanisation and population growth in urban environments are increasing the proportion of people who can benefit from nature-based solutions in urban spaces. Furthermore, these solutions are often aesthetically pleasing, much-appreciated features of a city; studies show that proximity to greenery can result in higher property values.[139] Finally, through the planning and development of cities and urban areas, nature-based solutions are a crucial tool for promoting biodiversity and ecosystems and their importance for cities as well as the surrounding landscape.[140]

Nature-based solutions are thus key elements in our urban environments for addressing the climate challenges facing today's cities, supporting biodiversity and ecosystem services, promoting our health and well-being, and creating vibrant, sustainable cities.

[137] Planting Healthy Air – The Nature Conservancy & C40 cities 2016, nature.org

[138] Stressad? Ta en dos natur, Swedish Environmental Protection Agency on YouTube

[139] Mazzotta et al. 2014

[140] Biologisk mångfald ger motståndskraft, PBL kunskapsbanken, National Board of Housing, Building and Planning

The city and its surroundings

The surrounding landscape outside urban areas has a major impact on the risk of flooding in the urban environment. This is true for areas like urban forests or areas that are upstream in the catchment area. There, land use can affect the soil's ability to retain water, thereby increasing the flood risk downstream. Even if the challenge in focus might appear to be restricted to the urban environment, it is important to widen your perspective and look at the entire landscape – to establish a landscape perspective.[141] For example, refraining from felling upstream forest areas can be a way to avoid new, or increased, flooding downstream in the urban environment. Another example is how coastal wetlands can protect against storms and mitigate the impact of flooding in urban areas and communities near the sea.

Ensure the right conditions for nature-based measures at an early stage

To determine the optimal nature-based solutions for an urban environment, local conditions such as hydrology, geology, topography, climate and vegetation must be carefully evaluated. Consideration must also be given to the design and availability of open spaces, since open stormwater management, infiltration and multi-functional surfaces require suitable areas to be reserved for these benefits in the right locations.[142]

As described in step 2 of this guide, this mapping already begins during the creation of the municipal master plan. Precisely by reviewing and specifying which areas could be covered by nature-based solutions, you can lay the right foundation in the master plan. For example, natural areas that are crucial for hydrological balance, such as wetlands or forest areas, can be identified and set aside in order to even out peaks in flows and reduce the risk of downstream flooding. Municipal stormwater strategies, cloudburst plans or detailed development plans[143] can also be important tools for enabling implementation.

The "green space factor" is a planning tool that can be used to secure a certain amount of vegetation or water in the built environment, in both development districts and public spaces.[144] It aims to create healthy habitats for people, animals and plants by creating a good microclimate and air quality, good soil quality and water balance, and recreational and functional open spaces, among other goals. The green space factor is thus a tool that benefits both ecosystem services and biodiversity in cities.

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[141] A landscape perspective means taking the context into account in addition to the object (or problem) level to include environmental aspects that are not limited to the individual object or problem.

[142] Mångfunktionella ytor: Klimatanpassning av befintlig bebyggd miljö i städer och tätorter genom grönstruktur, boverket.se

[143] Säkerställ ekosystemtjänster i detaljplan, PBL kunskapsbanken, National Board of Housing, Building and Planning

[144] Grönytefaktor – räkna med ekosystemtjänster, PBL kunskapsbanken, National Board of Housing, Building and Planning

The green space factor for development districts is measured as a ratio between the amount of "eco-efficient areas" and the district's total area.[145] Using this tool as an aid, you can calculate the percentage of functional green spaces relative to impervious surfaces. Examples of functional green surfaces include nature-based solutions like permeable surfaces, surfaces covered by trees, lawns or green roofs.[146]

The green space factor is also a key tool for fostering regular dialogue between the municipality and the builder about greenery in development districts and public spaces. By making the green space factor a stated objective in project planning, nature-based solutions can be planned for early in the planning process. This factor can thus be decisive for ensuring that different ecosystem services for climate adaptation are considered during planning and construction. Here[147] you can read more about the green space factor.

Examples of nature-based solutions in high-density environments

URBAN GREENERY AND GREEN INFRASTRUCTURE

Urban vegetation, such as city trees, urban forested areas, tree allées, hedges, parks, green walls and green roofs, home gardens and grassy areas give us a variety of benefits including reduced erosion, stormwater management (detention, infiltration, purification), carbon sequestration, aesthetically pleasing features, higher property values and noise reduction. The shade from vegetation and evapotranspiration regulate the temperature and can help reduce electricity consumption for cooling buildings.[148] Vegetation like shrubs and trees is also essential for stabilising soil and soil conditions by binding the soil with their roots.[149]

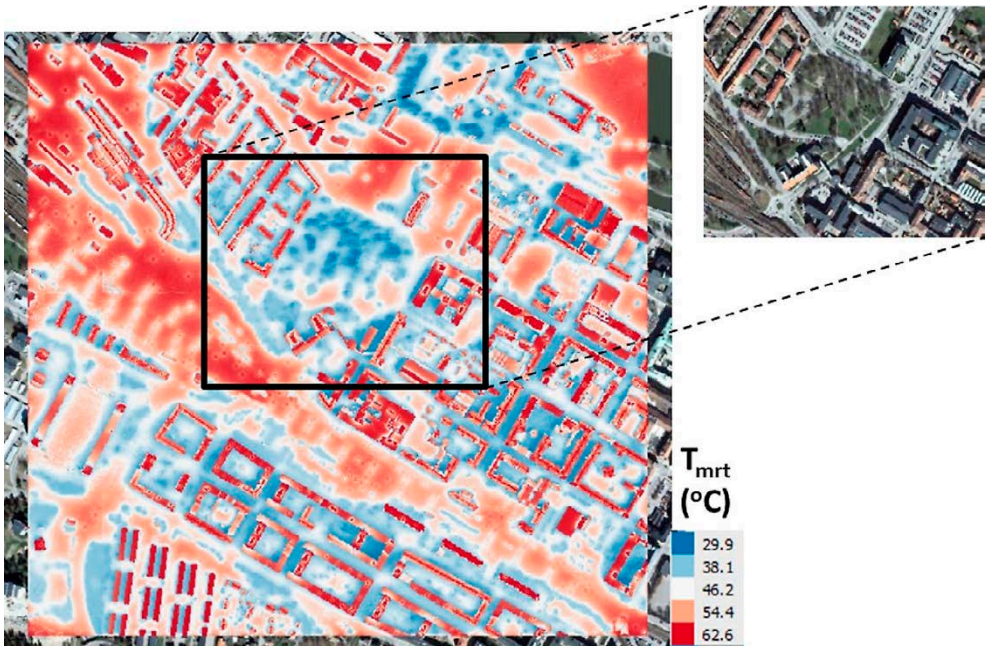
Urban vegetation and park areas also create recreational spaces, which bring physical and mental health benefits and are capable of cleaning the air by removing air pollutants.[150] Besides the direct benefits that urban vegetation gives us humans, it helps to improve the conditions for biodiversity, for example for insect pollination.

[145] Ekosystemtjänsternas bidrag till god urban livsmiljö, naturvardsverket.se
[146] Grönplanering bidrar till hållbar samhällsutveckling, naturvardsverket.se
[147] Grönytefaktor – räkna med ekosystemtjänster, PBL kunskapsbanken, National Board of Housing, Building and Planning
[148] Planting Healthy Air, The Nature Conservancy, 2016, nature.org
[149] Ras, skred samt kolsänka, PBL kunskapsbanken, National Board of Housing, Building and Planning
[150] Grönplanering bidrar till hållbar samhällsutveckling, naturvardsverket.se

Temperature regulation

Trees and other vegetation regulate and mitigate extreme temperatures, such as those during a heat wave, in two main ways. First of all, vegetation cover shades the ground surface and prevents solar radiation from reaching it, which in turn prevents heat storage and radiation from the surface and thus counteracts the urban heat island effect. To optimise this effect, tall trees should ideally be chosen over lower vegetation so that the canopy can provide as much shade as possible. Trees also evaporate water as they grow (transpiration), increasing their ability to store heat.[151] Both the transpiration effect and the shade effect from urban trees and vegetation have a significant ability to reduce the maximum temperature at street level during summer days (Figure 12). This increases pedestrians' thermal comfort while reducing the risk of harmful UV radiation.

Figure 12. The image shows how the mean radiant temperature (MRT, a measure of perceived temperature in the urban environment) is 30 degrees lower in the area that is shaded by buildings and urban greenery. Source: SMHI.[152]



[151] Some of the sun's energy was used to convert water into steam instead of increasing the air temperature, which instead causes a decrease in air temperature.

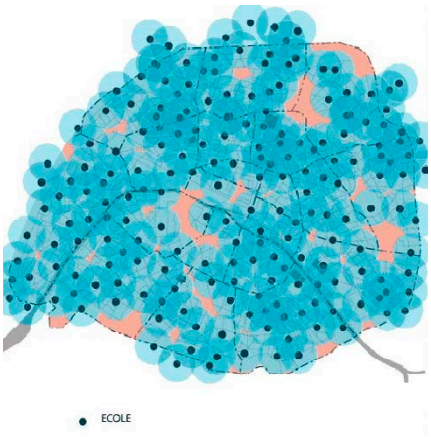
[152] Högre temperaturer i staden, SMHI

CASE

Impervious schoolyards become oases of coolness in the urban environment

An example of temperature regulation in urban environments where there are vulnerable groups comes from the Oasis project in Paris. In this project, schoolyards with an abundance of impervious surfaces were rebuilt and green features added to regulate temperatures. By working with schoolyards in particular, a network of cool spaces was created in the urban space. After school hours, the area is also open to the public and can be used as a cooling oasis in the urban environment during severe heat waves.

- Watch a short informational video.
- Read more about the project.



A "network" of schoolyards in Paris' inner city which, thanks to nature-based solutions, creates oases of coolness during a heat wave. Source: OASIS. OASIS – School yards: Openness, Adaptation, Sensitisation, Innovation and Social ties: Design and transformation of local urban areas adapted to climate change, working jointly with users, UIA – Urban Innovative Actions (uia-initiative.eu)

The maximum distance for cooling from an urban forest or park usually extends about as far away as the diameter of the park, and for a street tree, the cooling effect is strongest within a 30-metre perimeter from the tree.[153] The capability of urban trees to regulate temperature varies greatly depending on the species and is influenced by factors like the size of the tree or the density and thickness of its foliage. However, the most decisive factor in achieving a cooling effect is the size and density of the canopy. Larger trees with a high leaf area index cast a denser shaded area and will therefore be more effective at regulating temperature.[154]

In general, trees and vegetation should be chosen based on suitability given a city's climate zone and access to water. In countries like Sweden, deciduous trees are particularly suitable because they provide shade in the warm season and let through much-needed sunlight during the winter. Of course, the location of trees in the city also affects efficiency. The value is mainly optimised in dense urban areas with many inhabitants, or for temperature-sensitive individuals such as children or the elderly, who can benefit from the temperature regulation trees provide.

It can therefore be important to map where vulnerable groups move in the urban space. For example, parks, city trees or other green spaces can become important features near preschools or retirement homes.

[153] Planting Healthy Air – The Nature Conservancy & C40 cities 2016, nature.org
[154] Leaf area index is a measure for comparing tree leaf mass.

Stormwater management

As mentioned above, urban trees and urban greenery play a prominent role in managing stormwater (detaining, infiltrating and purifying), thereby reducing the risk of flooding and strain on water and wastewater systems. Healthy urban trees and green infrastructure have the capability to manage stormwater volumes in the following ways.[155]

- **Transpiration.** Trees absorb large amounts of rainwater from the ground for their photosynthesis.
- **Collection.** A tree's branches, leaves and trunk capture and absorb rainwater, reducing the amount of water reaching the ground and in turn detaining and reducing peak flow volumes.
- **Reduced permeation.** The canopy helps to reduce soil erosion by decreasing the volume and rate of precipitation as it falls through the foliage.
- **Increased infiltration.** Root growth and the decay process from leaves and organic matter increase rainwater infiltration in soil.
- **Phytoremediation.** Phytoremediation is a collective term for various ways of remediating contaminated soil, water and air with the help of plants. As the tree or vegetation captures water, it also captures different types of harmful chemicals and soil pollution. These are bound, stored or converted into less harmful substances by the vegetation.

To increase the ability of trees or vegetation to manage stormwater, planning and planting must be done with care. Soil composition and space for growth are crucial for a tree's ability to deliver the services expected. By designing the planting using the correct soil composition (porosity, permeability, infiltration rate) as well as enough space in the soil for growth, the tree's stormwater management capability can be optimised. To promote good permeability and storage capacity, structured soils are commonly used, where a layer of stones is placed under the topsoil. In this way, the conditions for infiltration, water storage and, in many cases, water purification are improved.[156] You can read more about tree planting for optimising stormwater management.[157]

Noise and air pollution

Urban trees and vegetation can also improve air quality by capturing airborne particles on their leaves. Vegetation can thus be used as a planning tool to promote ventilation in locations with air pollution, such as heavily trafficked streetscapes or areas with high foot traffic where people need to be protected from inflows of polluted air. However, optimised placement and plant selection are crucial for achieving a good air purifying effect.[158] Studies have shown, for example, that dense canopies over a busy road caused elevated levels of pollution in the street because the particles remained stuck under the canopy, while an optimised planting of vegetation (such as hedges) as a ground-level barrier lowered pollution levels on the lee

[155] Stormwater to Street Trees: Engineering Urban Forests for Stormwater Management
[156] Argument för mer ekosystemtjänster, naturvardsverket.se
[157] Växtbäddar i Stockholms stad – en handbok, 2017, leverantor.stockholm
[158] Janhäll 2015

side of the barrier.[159] It is also important to choose vegetation that has a high capacity for capturing air particles, and to plant trees at great enough intervals in busy streetscapes with lots of people to avoid particles getting stuck under the canopy.[160]

Urban vegetation also has a good ability to reduce noise levels in urban environments. Trees, shrubs and plant-covered surfaces like roofs and walls deflect sound waves to reduce sounds, compared with flat surfaces. Studies have shown that nature-based solutions can be as effective as traditional noise-cancelling features, such as embankments or planks. Furthermore, urban vegetation can indirectly contribute to good acoustic environments through the effects of wind, birdsong or rustling leaves, which are perceived as less disturbing. On the National Board of Housing, Building and Planning website, you can read more about noise control through nature-based solutions.[161]

Consider the risk of invasive non-native species

Regardless of why urban greenery is planned, it is important to bear in mind that planting new species not previously introduced at a specific site can negatively impact biodiversity and ecosystems. For example, some plants can quickly overtake their new environment and outcompete other parts of the natural ecosystem.[162] A changing climate might also affect how well a particular species will thrive in the future. Furthermore, different types of plants and trees may prove unsuitable for planting in an urban environment because of high pollen content. And finally, all possible outcomes of the solution must be evaluated early in the planning stage in order to minimise unwanted outcomes and enable trade-offs.[163]

This is because the plants or trees chosen might not be capable of managing stormwater or regulating temperatures as intended, or even worsen the situation at a particular site.[164]

On behalf of the Swedish National Board of Housing, Building and Planning, the Centre for Biodiversity at the Swedish University of Agricultural Sciences has developed a knowledge base[165] on non-native tree species.

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[159] Abhijith et al. 2017 Gromke et al. 2016.
[160] Planting Healthy Air, The Nature Conservancy, 2016, nature.org
[161] Reglering av buller, PBL kunskapsbanken, National Board of Housing, Building and Planning
[162] Samlad information om invasiva främmande arter, Swedish EPA, naturvardsverket.se
[163] Somarakis et al. 2019.
[164] Piton et al. 2019; Solcerova et al. 2017; Vaz Monteiro et al. 2017.
[165] Främmande trädarter i stadsmiljö, slu.se

URBAN AND PERI-URBAN WETLANDS

Wetlands have the ability to allow for a more even runoff by retaining and slowing water flows, even in an urban environment. This reduces the risk of flooding and can relieve existing stormwater management networks. Furthermore, the water-holding capacity of wetlands can mitigate the effects of drought and bolster groundwater formation in urban areas.

On the coast, wetlands can be used as a buffer to protect settlements and reduce the risk of flooding by attenuating the wave energy from storms. At the same time, several different benefits are created in addition to the climate adaptation benefits such as water purification,[166] carbon formation, biodiversity, recreation and aesthetically pleasing natural environments. By constructing, preserving and restoring existing wetlands in urban and peri-urban environments, flood risks from heavy rainfall can be reduced and stormwater management infrastructure offloaded. Within the scope of the Interreg project Building with Nature, a combination of nature-based solutions (wetlands, floodplains, stormwater ponds and two-stage ditches) in both urban and peri-urban landscapes has been implemented to reduce flood risks adjacent to Råån's catchment area in Helsingborg Municipality.[167]

As described in the section on wetlands, the construction of new wetlands requires the thorough investigation of the geotechnical and hydrological conditions at the specific site prior to implementation. If this is not done, the wetland might fail to manage the problems it was intended to solve, or even exacerbate flood conditions at the specific site.

[166] Bridgewater, 2018; Frantzeskaki et al. 2019; Liquete et al. 2016; Song et al. 2019; UNaLab, 2019.
[167] Case studies: Restoration streams of the Råån – Building with Nature, buildingwithnature.eu

CASE – JÄRFÄLLA MUNICIPALITY

An example of a stormwater system installation that acts as a kind of urban wetland comes from Järfälla Municipality. When planning the park Kyrkparken in a new district, this solution was created partly to manage future flood risks and runoff from nearby buildings. Through the nature-based solution, the water is detained and stored. Besides the park's ability to manage stormwater, the solution provides a recreational area for the public and the conditions for urban biodiversity. Work on the park took shape early on, in the master plan, highlighting the value of urban ecosystem services. Photo: Anki Weibull

▶ Read more about the project.

CASES LUND, LOMMA AND STAFFANSTORP MUNICIPALITY

An example of urban wetland restoration is found along the Höje river in Scania. There, three municipalities, Lund, Lomma and Staffanstorp, combined forces to restore over 80 wetlands along the catchment area in order to reduce the risk of flooding and counteract eutrophication, all while promoting the area's biodiversity and recreational spaces. In this case, the solution to the problem turned out to lie outside the urban perimeter and the individual municipality's decision mandate. Through a holistic approach, strategic intermunicipal collaboration, and close dialogue with the landowners concerned, the project yielded a successful result.

▶ Read more about the project.

Stormwater pond that stormwater is diverted to in open stormwater systems, the residential area of Augustenborg in Malmö. Open reflective ponds with shade-providing trees also provide coolness on hot days. Photo: Timo Persson.

STORMWATER PONDS AND OPEN STORMWATER SYSTEMS

In order to relieve public stormwater and sewage infrastructure (combined systems) from large volumes of stormwater during rain events, strategically located stormwater ponds and open stormwater systems (ditches, canals, open drainage systems) have become an increasingly common feature in urban areas.[168] The purpose of this type of solution is to divert, delay and, to some extent, treat stormwater, from urban settlements pre-discharge to the receiving waters.

A stormwater pond is often located near the infrastructure and buildings you want to protect. Properly designed stormwater ponds are capable of managing and detaining inflow during heavy rainfall. They can also help to treat stormwater by removing chemicals and other contaminants through infiltration and phytoremediation, as described in the section on urban greenery.

At high temperatures during the summer, stormwater ponds and open stormwater systems can help mitigate high temperatures through the cooling effect of evaporation. At the same time, these types of solutions can be designed to offer an aesthetically pleasing feature in the urban environment and support its biodiversity. However, they must be designed to prevent the increased risk of drowning incidents.

[168] Lund University, CEC Synthesis No. 4. Ekosystembaserad klimatanpassning – en kunskapsöversyn, 2017, lu.se

Malmö's Augustenborg district regularly experienced flooding during heavy rainfall.[169] To remedy the problem, a project was launched focusing on constructing canals and dams in an open stormwater system instead of the underdimensioned pipes that were under ground. The result was highly successful, and the system has proven to have a good capacity for managing significantly larger amounts of rain than nearby comparable residential areas during heavy rainfall events.[170]

PERMEABLE SURFACES

The high proportion of impervious surfaces in built-up environments causes rapid runoff to stormwater and sewage systems. Nature-based solutions, such as grassy surfaces, parks and trees, can help to manage and detain stormwater and to counteract flooding. Yet there are other surfaces, such as parking lots, car and bike paths, and sidewalks, that do not allow for any grass cover. In such locations, permeable surfaces – engineered solutions inspired by nature and their ability to infiltrate rainwater – can offer an alternative.

Different types of permeable surfaces, such as grass-reinforced concrete pavement, permeable paving stones, gravel surfaces or permeable asphalt and concrete can provide flow detention, infiltration and, in some cases, even local groundwater recharging.[171] But many permeable surfaces require regular care in order to function, since the material's pores can get clogged by particles. This type of solution is common in Belgium, which has seen successful outcomes.[172]

STORMWATER RUNOFF PARKS

A stormwater runoff park is a collective term for strategically planned infiltration basins in urban areas. During heavy downpours, they can manage and detain stormwater and thus help to avoid flooding damage in surrounding areas.

A stormwater runoff park can be created by lowering an existing park or grassy area, and designing a new low point with directed drainage from nearby areas.

However, an existing land area does not always need to be lowered; instead, natural low points can be utilised or the park can be planned when new residential areas are being planned. The optimal location of the stormwater runoff park is determined by the topographic conditions within the selected area, which should be studied during planning and construction. Between cloudburst events, this hilly and grassy park area can be enjoyed by the public as a multifunctional area for recreation, or serve as part of a schoolyard or a football pitch.[173]

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[169] Öppen dagvattenhantering i Malmöstadsdelen Augustenborg, fördjupning, SMHI

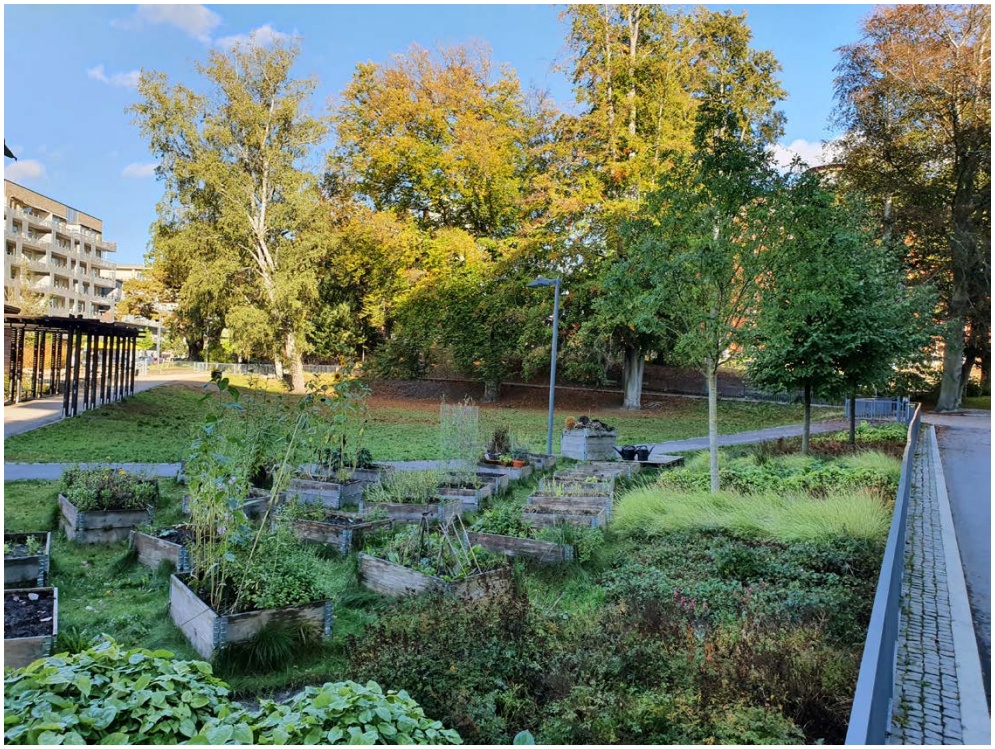
[170] Gröna lösningar gav skydd mot översvämning, slu.se

[171] Genomsläpplig beläggning, Stockholm Vatten och Avfall, stockholmvattenochavfall.se

[172] Vad kan man göra för att bevara, utveckla eller skapa ekosystemtjänster på hårdgjorda ytor? – PBL kunskapsbanken, National Board of Housing, Building and Planning

[173] Fotbollsplan blev utjämningsmagasin för dagvatten i Växsjö kommun – kostnad och nytta, Klimatanpassning.se

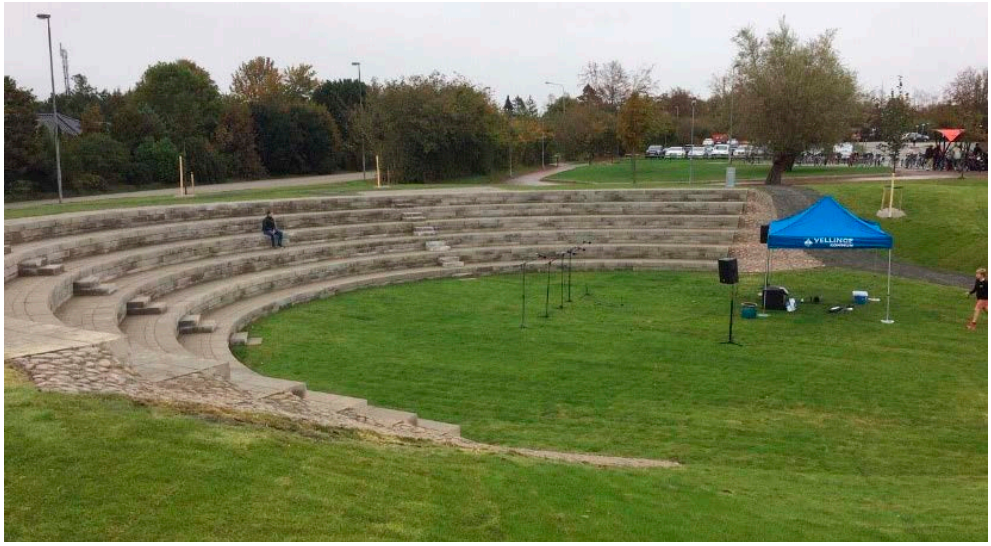
Stormwater runoff parks are a simple intervention for managing and detaining larger volumes of stormwater in the urban environment while providing a surface for a park or other form of recreational area during dry spells.



In Norra Djurgårdsstaden in Stockholm, a stormwater runoff park has been planned as a natural park area in a new residential area. The solution can manage stormwater from the buildings while being a recreational area for the residents by offering a space for raised bed gardening.[174] Photo: Timo Persson

[174] I Norra Djurgårdsstaden får naturen göra jobbet, C/O City

In the residential area of Söderkulla in Malmö, which was hit hard by flooding during the cloudbursts that pummelled the city in 2014, an existing park was lowered in order to manage runoff from surrounding homes. The park can still be used by the public as a recreational area and now has new features, such as a dog park.[175] Photo: Timo Persson



In Vellinge Municipality, Sandplaneskolan's schoolyard was converted into a multifunctional surface, partly to reduce the risk of flooding from cloudbursts. Thanks to the conversion, large volumes of stormwater can be managed, which reduces the load on the municipal stormwater system. At the same time, an amphitheatre was built for concert and school graduations, space for recreation and sport, and a garden for nature instruction.[176] Photo: Carl Nelin, Vellinge Municipality

[175] Invigning av skyfallsanpassade parker i Söderkulla, City of Malmö, mynewsdesk.com
[176] Idag invigdes Sandeplanskolans nya skolgård, Vellinge Municipality

CASE UPPSALA MUNICIPALITY

In the Rosendal district of Uppsala Municipality, a densification of the city is underway. Many new homes have been built and more are being planned. In the city' development process, climate adaptation and stormwater management efforts have resulted in an extensive system of rain gardens. The rain is filtered down through the lush rain gardens where the water is detained and purified, and then purified one last time in connected stormwater ponds.

▶ Read more about the project.

RAIN BEDS, RAIN GARDENS AND BIOFILTERS

To manage stormwater in urban spaces, different types of plant beds can offer a simple yet effective solution. With such solutions, water is taken up by plants or trees, stored, evaporated and purified to some extent before the excess water is diverted. This type of detention measure both reduces the amount of stormwater and extends the time from when the rain reaches the bed until it puts a strain on existing stormwater systems.[177] Nature-based solutions like rain gardens, plant beds, rain beds, open bio-dykes and meadows with seepage water thus become effective complements to existing stormwater system.[178] Rain gardens also help to treat stormwater by removing pollutants that the water has accumulated from parking lots, roads or other impervious surfaces.[179]

[177] Växtbäddar_i_stockholms stad – en handbok, 2017, leverantor.stockholm
[178] Vinnova: Klimatsäkrade systemytor för urbana miljöer, klimatsakradstad.se
[179] Regnrabatter i Göteborg, fördjupning, Klimatanpassning.se

In Norra Djurgårdsstaden in Stockholm, rain gardens have been installed in several locations in the residential area in order to manage and treat stormwater. Here, a walking path through the vegetation was planned. Photo: Timo Persson

▶ Read more about nature-based solutions in Norra Djurgårdsstaden.

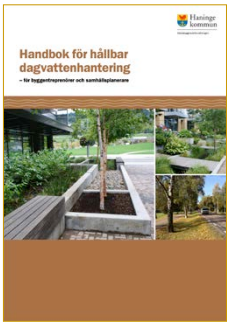
A *biofilter* works in the same way as a rain garden and is a special function for detaining and managing stormwater in urban environments. Similar to a rain garden, biofilters consist of a bed with vegetation and a layer of soil underneath that is designed for storing water. Biofilters can have a diversion function that is directly linked to the water and wastewater system or, alternatively, diverted down into the soil.[180] Finally, these types of solutions can be designed so that they also benefit urban pollinators, such as bumblebees and other bees, and they serve as an aesthetically pleasing feature of the urban environment. The website Vaguiden.se contains a publication describing how to install rain garden.[181]

READING TIPS

More handbooks on sustainable stormwater management

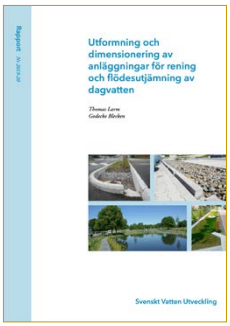
HANINGE MUNICIPALITY has produced a handbook containing guidelines and principles for sustainable stormwater management. It also contains tips and examples of how to design and dimension stormwater facilities.

▶ Read the handbook.



SVENSKT VATTEN UTVECKLING has published the report "Utformning och dimensionering av anläggningar för rening och flödesutjämning av dagvatten". The report compiles general recommendations on the selection, function and design of different stormwater solutions.

▶ Read the report.



[180] Vad kan man göra för att bevara, utveckla eller skapa ekosystemtjänster på hårdgjorda ytor? – PBL kunskapsbanken, National Board of Housing, Building and Planning

[181] Öreingevägen_movium_fakta_22015_rangbaddarslutlig, dagvattenguiden.se

CASE – ÄNGELHOLM MUNICIPALITY

Multifunctional rain gardens in Munka Ljungby, Ängelholm Municipality

In a residential area in Munka Ljungby, rain gardens have been installed in the street space in order to prevent basement flooding. In addition to the flood hazard, the streets were wide and dangerous to cross due to traffic. To address both problems at the same time, rain gardens were designed as speed bumps in the street space so that stormwater could be managed while increasing traffic safety. The measure was implemented in line with the municipality's applicable stormwater policy, which highlights nature-based detainment solutions.

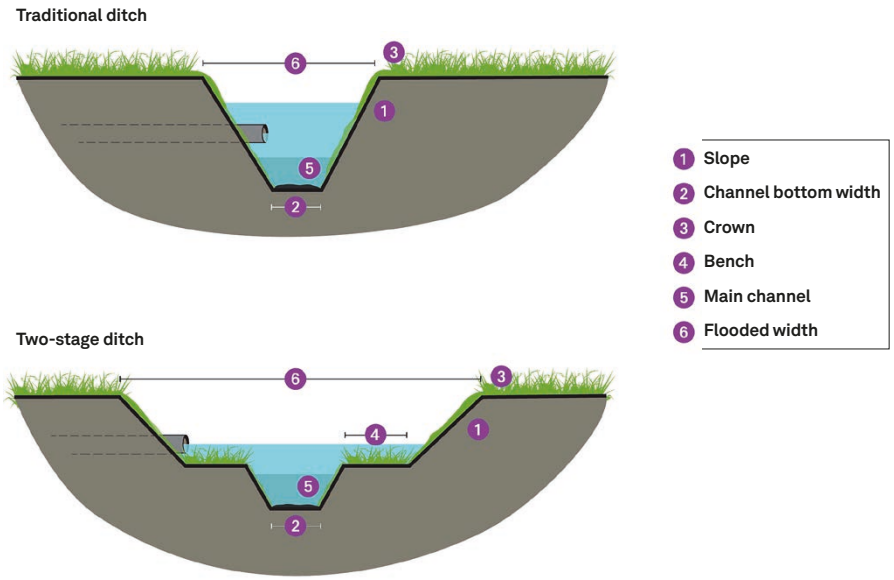
▶ Read more about the project.

TWO-STAGE DITCHES AND SWALES

A *two-stage ditch* is a form of ditch for managing runoff. It is designed in two stages, with the ditch slopes divided as if into steps (Figure 13). In the centre of the ditch, a channel is made that is deeper and narrower than that of traditional ditches, which is sufficient to manage the flow of water during normal flows. The slopes are made wider and flatter, enabling the two-stage ditch to manage large amounts of water during heavy rains and in turn to reduce the risk of flooding.[182]

When the water flow becomes higher than the narrow main channel can handle, it falls onto the flat benches, forming a kind of temporary wetland environment.[183] The flat benches in the slopes of the ditch also slow the water's speed at high flows and thus also reduce soil erosion. This design, with the narrower main channel at the bottom of the ditch, enables sufficient water flow for aquatic organisms even at drier periods during the summer.[184] Two-stage ditches can thus help reduce the risk of flooding, nutrient leaching and promote biodiversity.[185]

Figure 13. A two-stage ditch where flat benches have been installed with a narrower main channel for water flow at the bottom. The flat benches and wide design enable the ditch to manage large amounts of water while creating the conditions for water treatment, nutrient binding, reduced erosion and biodiversity. Illustration: Swedish Board of Agriculture



[182] Anlägg tvåstegsdiken – Greppa
[183] Tvåstegsdiken – Rååns Vattenråd, raan.se
[184] lararhandltvastegsdiken, slu.se
[185] Råån – two-stage channels impact on biodiversity and nutrient retention, lansstyrelsen.se

CASE Helsingborg Municipality

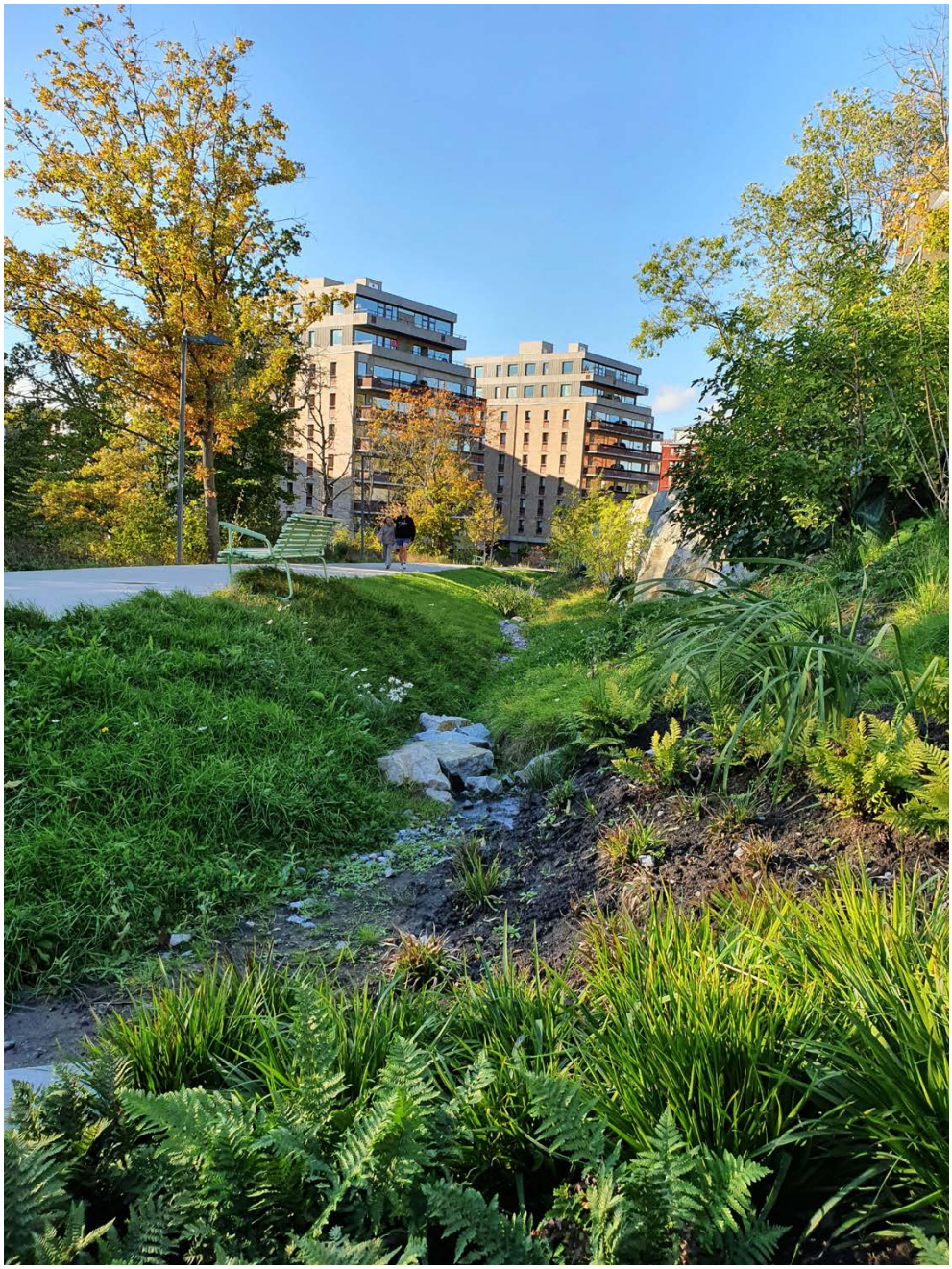
An example of the construction of two-stage ditches adjacent to the urban area can be found in Råån's catchment area in Helsingborg municipality. In the catchment area, several two-stage ditches were implemented to reduce peak flows and flood risks in downstream urban areas. The installation and restoration of the two-stage ditches also helped to minimise nutrient leaching from abutting farmland, reduce soil erosion at high flows and improve the conditions for biodiversity. Read more about the results:

The Before and After images show how a two-stage ditch was created along Lussebäcken (part of the Råån river basin) in Helsingborg Municipality. The Before image clearly indicates the extensive erosion the watercourse was subjected to at high flows before the two-stage ditch was built.
Source: Rååns Vattenråd

The fact that two-stage ditches take up more land than traditional ditches must be kept in mind, as well as the fact that their installation constitutes a water operation requiring permission from the Land and Environment Court.[186] In the Swedish Board of Agriculture's guidance, you can read more about installing two-stage ditches.[187]

Two-stage ditches are most common in the agricultural landscape, but can be installed in and adjacent to urban areas in order to reduce peak flows and the risk of flooding. One example can be found in Växjö, where a four-lane road was converted into a two-lane road to make room for a two-stage ditch.[188] The water levels in the canal fluctuate widely, but since the canal has been designed as a two-stage ditch with sloping sides, the water-holding volume multiplies as the water surface rises.

[186] Chapter 11, "Vattenverksamhet", Swedish Environmental Protection Agency, naturvardsverket.se
[187] Från idé till fungerande tvåstegsdike: en vägledning 2016. Swedish Board of Agriculture, jordbruksverket.se
[188] Examples of green solutions for climate adaptation in cities. PBL kunskapsbanken, National Board of Housing, Building and Planning



Swales and two-stage ditches are examples of open stormwater solutions that can be implemented to detain and divert stormwater during cloudbursts. At the same time, this type of nature-based solution can become a verdant recreational feature of the cityscape, as in this example from Norra Djurgårdsstaden in Stockholm. Photo: Timo Persson.

Swales are a common form of ditch in urban environments and are installed to detain and divert stormwater from roads, streets and other impervious surfaces. A swale is a shallow, gently sloping vegetation-covered ditch that runs along impervious surfaces whose purpose is to collect and detain runoff. When water collects in the swale, gravel and coarser particles can also be captured before the stormwater is diverted to the existing stormwater network.[189]

Although swales are often grassy, they can also be planned using higher vegetation for improved purification capacity, for example in a parking lot.[190] Swales are also ideal for snow storage and diversion of snow-melt during the winter.[191]

VEGETATION-COVERED WALLS AND ROOFS

A now well-established feature of many urban environments is vegetation-covered walls and roofs, called green roofs and green walls. In dense urban environments where space is at a premium, they can help to address climate-related challenges like high temperatures or heavy rainfall without competing for space.[192] Green roofs with a thick substrate layer can, for example, help to manage stormwater locally. Lush green walls can contribute to a positive microclimate next to a building. Through the shade effect of this vegetation, the building absorbs less solar radiation[193] while the vegetation's transpiration cools down the building and its surroundings.

A study from Chicago determined that green roofs could lower indoor temperature in a building by as much as 3 degrees, helping to reduce the building's energy consumption.[194] Studies have also found that green roofs have the ability to manage between 25 % and 100 % of rainwater that hits the roof surface, depending on root depth, angle and volume of rain. Regardless of the conditions, green roofs are more able to detain and infiltrate stormwater than conventional roofs, and can thus reduce the load on existing stormwater management systems.[195]

[189] I mark, Dagvatten, stockholmvattenochavfall.se
[190] Svenskt Vatten Utveckling – Utformning och dimensionering av anläggningar för rening och flödesutjämning av dagvatten, svensktvatten.se
[191] Svackdike, VA-guiden
[192] Dickhaut et al. 2017; Perini and Rosasco, 2013; Oberndorfer et al. 2007.
[193] Lund University, CEC Synthesis No. 4. Ekosystembaserad klimatanpassning – en kunskapsöversyn, 2017, lu.se
[194] Smith and Roebber, 2011.
[195] Richter and Dickhaut, 2018.

READING TIPS

Grönatakhandboken contains guidance, information and examples of green roofs, from installation, load-bearing capacity, and fire and moisture safety to design, plant selection and specific cases.

▶ Read the report.

Green roofs can also help to improve water quality by detaining and purifying rainwater.[196] Furthermore, this verdant feature in the urban environment provides aesthetic and recreational values[197] that can positively affect property values,[198] while creating new environments for urban wildlife.

The most common type of green roof is an *extensive green roof*, which has a rather thin layer of substrate (about 20 cm) ideal for various succulents like sedum. However, extensive green roofs have poorer properties with respect to stormwater management. Roofs with thicker substrates are called *intensive green roofs*, which because of their depth enable shrubs and trees to be planted, thus creating better stormwater management capabilities. Green and living walls,[199] in turn, usually consist of a mix of climbing plants that are planted in a bed on the ground adjacent to the wall. Today, it is becoming more common to use a *cassette system*, a modular system attached to the outside of the wall that serves as the base for inserting the plants. When plants cannot be planted along the ground for some reason, this type of solution makes an excellent option.[200]

[196] Gröna tak, fördjupning, SMHI
[197] Grönplanering bidrar till hållbar samhällsutveckling, naturvardsverket.se
[198] Planting Healthy Air The Nature Conservancy & C40 cities 2016.pdf, nature.org
[199] IVL, Utmaningar och möjligheter med levande väggar i ett svenskt klimat, malmo.se
[200] Grönskande fasader_projektblad, Vinnova, malmo.se

Green walls can become an attractive feature of the cityscape that promotes urban biodiversity, while helping to regulate temperature and manage stormwater. Photo: Timo Persson.

Green roofs should be installed according to the building code from the National Board of Housing, Building and Planning, as should other covering materials. This entails high standards for both fire and moisture safety during construction and maintenance.[201] Under the code, combustible roofing like a green roof must be installed according to a certain type of classification (BROOF(t2)) that requires the roof covering to be evaluated and tested in order to prevent fire spread between buildings or flashover.[202] Another challenge is that green roofs are complicated to install on roofs not originally designed to handle a substrate layer and vegetation.[203]

The PBL kunskapsbanken on the website of the National Board of Housing, Building and Planning contains information about the rules that apply for installing green roofs.[204]

[201] Gröna tak, PBL kunskapsbanken, National Board of Housing, Building and Planning
[202] Brandskyddskrav för taktäckning och gröna tak, PBL kunskapsbanken, National Board of Housing, Building and Planning
[203] Planting Healthy Air – The Nature Conservancy & C40 cities 2016, nature.org
[204] Gröna tak, PBL kunskapsbanken, National Board of Housing, Building and Planning

READING TIPS

Green innovation in the City of Malmö through the BiodiverCity project

BiodiverCity ran from 2012 to 2018 and was aimed at developing products, services and processes that promoted and increased the city's biodiversity. Among other activities, innovation projects for developing green roofs, facades and walls were carried out together with the City of Malmö, Vinnova, universities, property companies, developers and others in Malmö. The City of Malmö's website contains more information about the outcomes of the projects that installed green roofs and walls on various properties around Malmö.
Photo: City of Malmö.

▶ Read more here.

Forest landscapes

Just over two-thirds of Sweden's land area is covered by forest.[205] Most of this forested area consists of productive forest, while about 9 % is officially protected.[206] In Sweden, the forest has long been a critical resource. It still is, but the use of the forest has changed over the last hundred years.

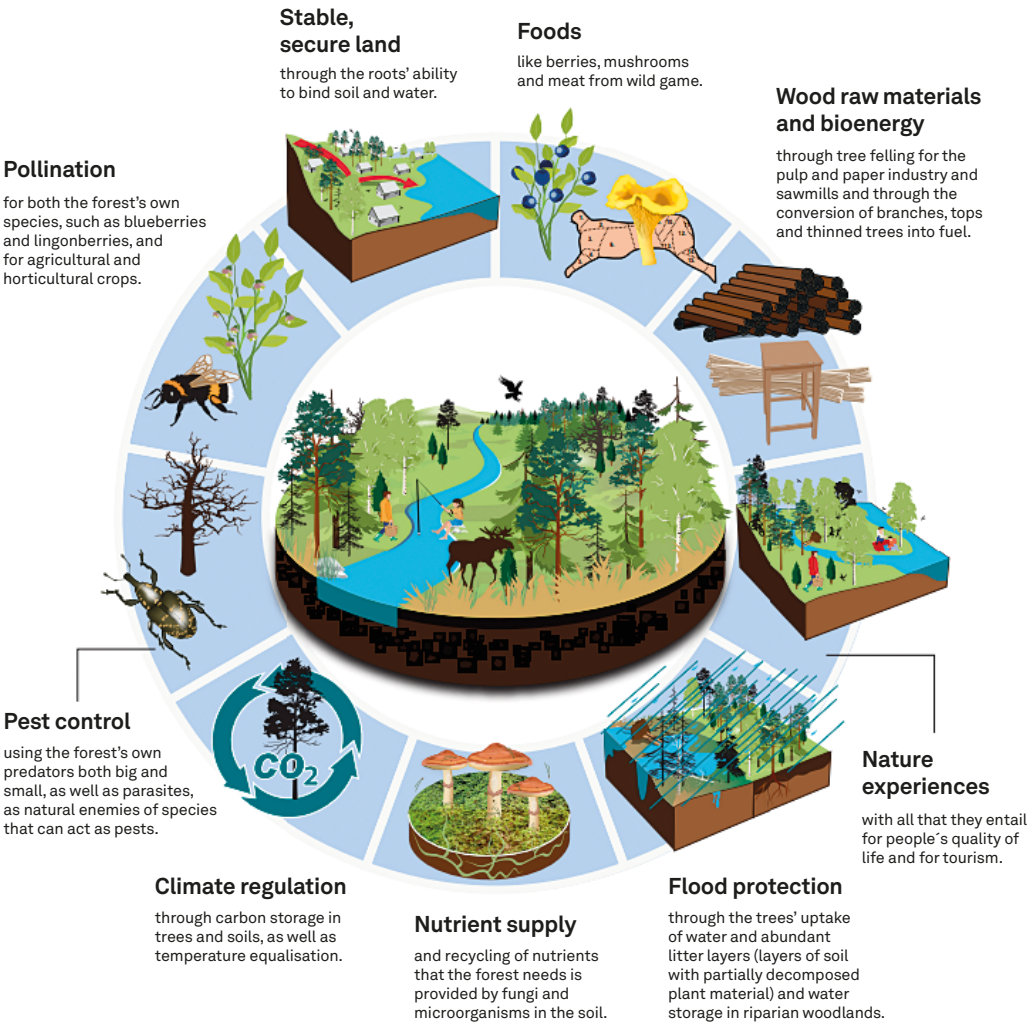
In the past it was common for cows to roam and graze in the forest, and the division between agriculture and forestry was not a clear one. But the forest is much denser nowadays, partly because forest grazing has ceased for the most part and the forests is dominated by conifers. Almost all forests in Sweden are managed using even-aged management practices with single-stage or two-stage stands, which has led to a homogeneous forest landscape. In addition, forest roads have caused the fragmentation and draining of the landscape towards desiccation. The purpose of this transformation has been to increase production from the forest. However, this has resulted in a forest landscape depleted of biodiversity, where there are too few habitats for many of the forest's plants and animals to survive.[207] In parallel, because the forests offer an alternative to fossil-based raw materials and thus play a part in transitioning to climate neutrality, the demands on them are great.

FOREST ECOSYSTEM SERVICES

Forest biodiversity and ecosystem services are fundamental to people and society, not least when it comes to climate adaptation. Growing forests help to reduce flooding, prevent landslides and erosion, regulate temperature and contribute to purification and groundwater recharge. The forest can also offer other ecosystem services, such as recreation and outdoor activities, has cultural and aesthetic values, and provides forest raw materials and bioenergy. Figure 14 illustrates the forest's various ecosystem services.

[205] Monitor 22
[206] Skyddad natur i siffror, naturvardsverket.se
[207] Swedish EPA 2015

Figure 14. Forest ecosystem services. Source: Government Offices website.[208]



[208] EkosytemtjänsteriSkogen_A3, regeringskansliet.se

Forests and a changing climate

Forests and Swedish forestry are impacted by climate change. With a warmer climate, Sweden will have a longer growing season and a higher concentration of carbon dioxide in the atmosphere, which will benefit the productivity of vegetation and in turn increase the production of biomass in the forest. Because of a warmer climate, even today the climate zones in Sweden have moved northwards by about 5–10 kilometres each year.[209]

Forest growth is highly likely to continue to increase in the coming decades. At the same time, the risks are shifting. Higher temperatures are driving more attacks by insects and fungi that naturally occur in our latitudes, and new pests can spread to Sweden. The spruce bark beetle, spruce root rot and the pine weevil are already causing costly damage to the forestry industry.

The fire risk season is expected to be extended in the future,[210] and the incidence of prolonged drought is increasing. Both fires and spruce bark beetles are actually natural disturbance features in Swedish forests – disturbances that have created favourable living conditions for many endangered species associated with the forest. With a changing climate, the frequency and extent of these disturbances are altered. In addition, the snow-free season is becoming longer and the risk of storm precipitation is increasing in milder winters as soil frost periods get shorter.[211] All this affects forestry practices, the forests themselves and biodiversity.

Climate adaptation in the forest is about implementing measures that boost the forest's resilience to negative impacts, helping society at large to adapt and creating greater resilience in forestry. By creating variety in the forest and promoting nature's own ability to withstand adversity, the forest landscape can be adapted to both current and future climate change while preserving biodiversity and enhancing the functions and services of ecosystems.

Examples of nature-based solutions in forests

Nature-based solutions in forests can be divided into two groups. One involves the preservation of existing forests, and the other entails measures for creating diversity in forests to increase their resilience.

- Preserving and protecting forests.
- Varied forestry, with features like these:
  - Mixed forests
  - More deciduous trees
  - More wetlands
  - Agroforestry
  - Site-adapted forestry
  - Continuous cover forestry

[209] Klimatanpassat skogsbruk, Swedish Forest Agency
[210] Report, msb.se
[211] SMHI, 2019

PRESERVING AND PROTECTING FORESTS

The role of trees in regulating water flows is significant. The existing forest plays a big role in how much water runs off of an area. In a closed spruce forest, for example, upwards of 40 % of precipitation in one summer can return to the atmosphere as the rain gets trapped in the tree canopies and evaporates. In addition, rain in the forest is retained by the trees as they suck up the water.[212] Preserving existing forests can therefore be a simple yet effective nature-based solution if there are flooding problems downstream in a catchment. This is because the load on downstream areas is reduced, both in terms of water and nutrients. Preserving a forest usually ensures that other ecosystem services the forest provides also remain in the area.

Forests with high conservation values can be granted formal protection. For example, it might be possible to designate an area as a nature reserve (done by the municipality or county administrative board). More information about the process of establishing nature reserves is available on the Swedish EPA's website.[213]

A DIVERSE FOREST LANDSCAPE

A greater diversity of both tree species and harvesting techniques can constitute effective nature-based solutions. More diversity not only increases the resilience of ecosystems, but provides the landowner or user with some protection through risk diversification – so the entire operation is not affected if a particular tree species is adversely affected by climate change. There are several different ways to create more variety in the forest to increase resilience and adapt to a changing climate. The solutions, which can be used individually or in combination, contribute to an even more richly varied forest and forestry. We offer some examples below.

MIXED FORESTS

If a forest consists of a single tree species, the area's ability to generate different ecosystem services decreases and resilience decreases. A *mixed forest stand* of spruce, pine and deciduous forest therefore plays an increasing role in a changing climate. Mixed forests are able to grow more robustly while providing other ecosystem services.[214] One study has found that mixed forests in Sweden provide more biomass and other ecosystem services compared with forests that have just one tree species.[215]

Studies from storm Gudrun in 2005 showed that spruce was overrepresented among the types of storm-downed trees.

Mixed forests with both deciduous and coniferous trees are less vulnerable to storm damage, and even to pest infestations, than a monoculture of conifers. In addition, since many pests and harmful fungi are tree-specific, the risks of pest

[212] rapport201713skogensekosystemtjansterstatusochpaverkan.pdf, skogsstyrelsen.se
[213] Vägledning för arbetet med att bilda naturreservat, Swedish EPA, naturvardsverket.se
[214] Jonsson, et al. 2019
[215] Jonsson, et al. 2020

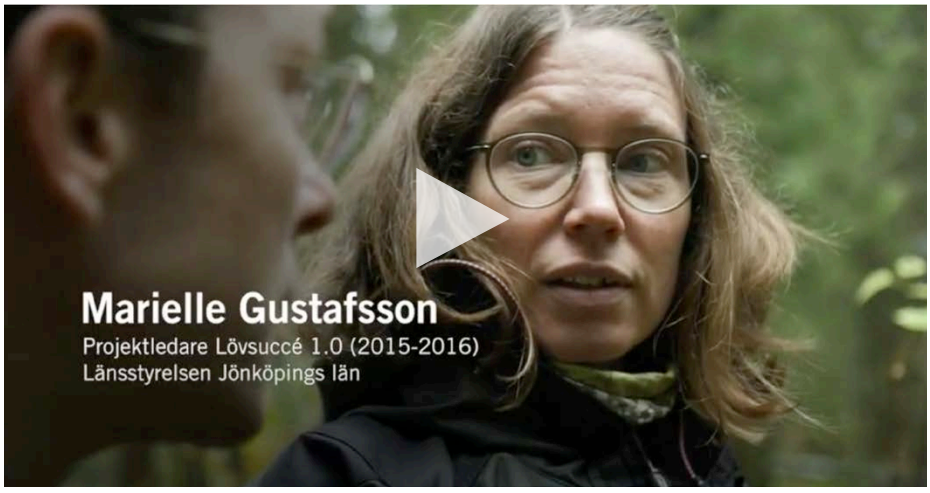
infestation in forests with diverse tree species are reduced. Measures that counteract the risk of trees being downed simultaneously reduce the risk of infestation by the spruce bark beetle.[216]

MORE DECIDUOUS TREES

Some of the benefits of more deciduous trees in the forest are described in the previous point about mixed forests. Crown fires are rare in purely deciduous forests, so deciduous forest fires are less intense and spread more slowly; the more leaves there are, the more they can help to keep forest fires at bay. Even stretches of deciduous forest throughout the landscape can limit the spread of potential forest fires.

CASE

The project Lövsuccé 2.0 is being run in Småland by the Federation of Swedish Farmers in collaboration with the Swedish Forest Agency, county administrative boards and other stakeholders. The project aims to increase the proportion of deciduous trees in different succession stages in the landscape by inspiring foresters to see the business opportunities that can lead to more sustainable growth and profitability.[217] By increasing the amount of leaves in their forest holdings, they can improve the forest's resilience to climate change.[218]



[216] rapport201708.skogsstyrelsensarbeteforokadklimatanpassninginomskogssektorn.pdf
[217] Lövsuccé 2.0 i landskap och företag, Federation of Swedish Farmers
[218] Rytter, 2019.

MORE WETLANDS

Today's forest landscape is heavily impacted by drainage and is thus more sensitive to drought. With the exception of some wetlands such as marshes, which can dry out in extreme weather, wetlands in the forest have the potential to limit the risk of fire. In general, wetlands with a natural hydrology can retain water in the landscape and are thus areas that are less susceptible to fire. Installing, preserving and restoring wetlands in the forest landscape can therefore help adapt the forest to a future climate of higher fire risks and drought stress.

AGROFORESTRY

Agroforestry is a collective term for the combination of agriculture with forestry, where trees or other perennial plants are grown and integrated with animal husbandry or crop cultivation. The focal point of agroforestry is agriculture, since the presence of trees among crops and animals helps to reduce erosion and damage from flooding and increase water retention capabilities. Agroforestry examples include agricultural crop production for food that is combined with biomass production (for example, from poplars).[219] Although agroforestry is primarily grounded in agriculture itself, it can sometimes offer a solution from a more forest-oriented perspective in that it creates variety.

SITE-ADAPTED FORESTRY

Adapting forestry to a specific site is an effective adaptation measure in terms of reducing drought risk, the downing of trees and pest infestation, and improving biodiversity.[220] This means that forest management is adapted to the conditions at each growing site, and the site determines which tree species will be planted or saved and how the forest will be managed. However, this does not lead to greater variation by default even if it supports climate adaptation. In Häradsmarken, stand adaptation is applied.[221]

[219] Torralba et al. 2016.
[220] Lund University, CEC Synthesis No. 4. Ekosystembaserad klimatanpassning – en kunskapsöversyn, 2017, lu.se
[221] Klimatanpassning av skog, Häradsmarken, fördjupning, SMHI

CONTINUOUS COVER FORESTRY

Continuous cover forestry involves adapting different forestry practices to benefit various ecosystem services and biodiversity. Single-selection cutting, group selection or a shelterwood system are all examples of continuous cover forestry practices that share a common trait: the avoidance of clearcutting.[222]

According to the Swedish Forest Agency's report "Klimatanpassning av skogen och skogsbruket",[223] continuous cover forestry can sometimes be a way to adapt operations to a changing climate. This is especially true of erosion-sensitive soils, which might become more exposed in a changed climate during winters without ground frost. This is also true more generally because a higher percentage of established forests give greater protection against flooding. In addition, continuous cover practices improve the conditions for biodiversity as habitats shrink due to the combination of climate change and intensive forestry.

Continuous cover forestry reduces the likelihood of extensive damage in the event of a storm, increased root rot or pest infestation,[224] yet it means lower growth. The method has been introduced as a climate adaptation measure both in Sweden and worldwide, and is a vital way to preserve the sense of a forest and to promote outdoor recreation and reindeer husbandry. It thus benefits multiple ecosystem services. Continuous cover forestry can involve different approaches. The Future Forests research programme has compiled information from different continuous cover forestry practices.[225]

On Klimatanpassning.se, you can read about a much-discussed practice called the Lübeck model.[226] There, the method is described as an "ecosystem-based forestry method that strives for the managed forest to be as similar to natural forest as possible." They are working on several ways to achieve this goal, including stand adaptation and continuous cover forestry with natural regeneration, and are striving to create resilience by safeguarding biodiversity. Timber yields from these forests are acknowledged as being somewhat lower, something that is accepted because of increased resistance to disturbances and thus yields that can be secured.

[222] Swedish Forest Agency, 2020.
[223] Report 2019/23, Klimatanpassning av skogen och skogsbruket, skogsstyrelsen.se
[224] Lund University, CEC Synthesis No. 4. Ekosystembaserad klimatanpassning – en kunskapsöversyn, 2017, lu.se
[225] https://www.slu.se/globalassets/ew/org/centrb/f-for/old/pdf/ff-rapport_hyggesfritt_skogsbruk_en_kunskaps-sammanstallning-2017-04-02.pdf
[226] Variationsrik skog klimatanpassar skogsbruket, SMHI

Agricultural landscapes

In Sweden, we have just under 2.6 million hectares of arable land and 0.4 million hectares of pastureland.[227] In the past, the use of agricultural and forest land was more closely intertwined and it was common for animals to graze in the forest.[228] Nowadays animal husbandry is concentrated to fewer places, and the total area for agricultural land is shrinking with each passing year. This is happening either via land abandonment, usually in forested areas, or through the development of otherwise productive land. Farmland is a key resource – if arable land is developed, future cultivation is usually rendered completely impossible.

The agricultural landscape is dominated by fairly open lands. The plains often have more vast swaths of open space, with big fields and few barriers to cultivation. It is often more mosaic-like in medium-altitude pastures and in woodlands, which contain rock outcrop features and other environments that are not directly put to use. Here, for example, the variation is greater in terms of the presence of trees and shrubs as well as wet and drier environments.

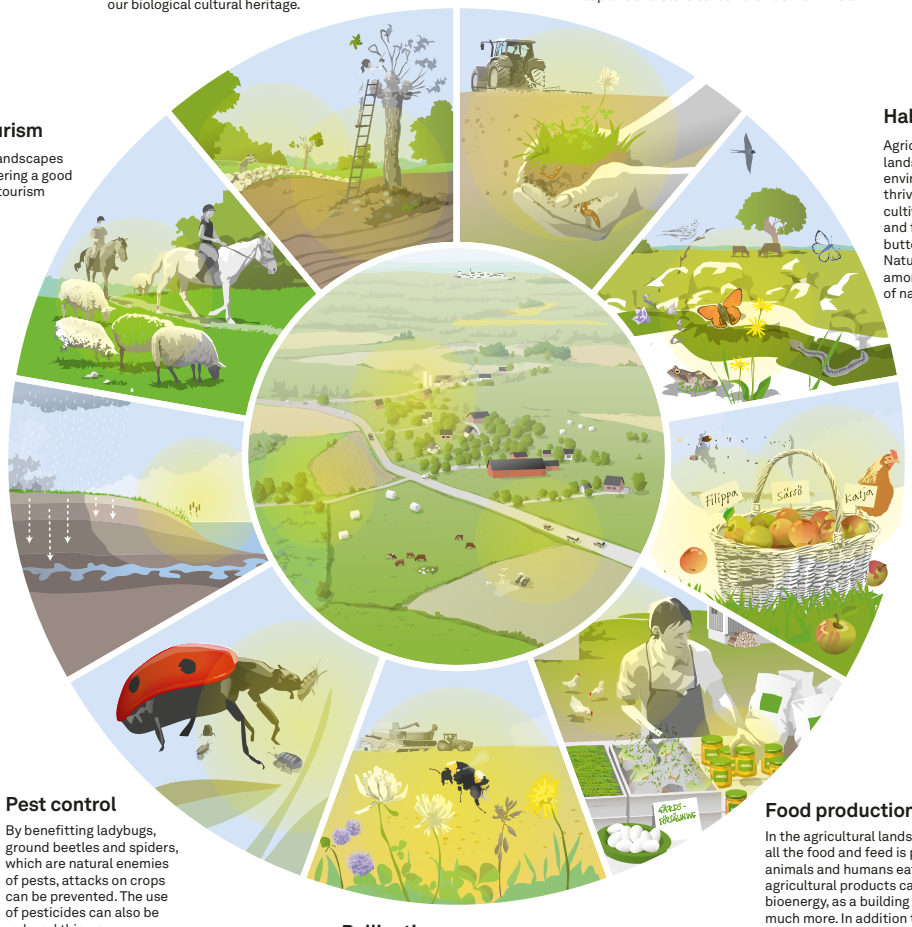
THE ECOSYSTEM SERVICES OF AGRICULTURAL LANDSCAPES

The agricultural landscape provides us with a wide array of ecosystem services – food and energy, water purification and outdoor recreation, to name a few (Figure 15). Arable land can also act as a buffer for high water flows. And without grazing animals, the landscape would become overgrown, putting an end to a landscape with high biodiversity and a long natural and cultural history. Furthermore, both fields and pastures bind carbon and contribute to achieving our climate targets.

Traditionally, optimising the conditions for producing food and bioenergy has been in focus, often at the expense of other ecosystem services. One example of this is regulating water through land drainage, a previously widespread method of creating more arable land. Today almost half of the farmland cultivated in Sweden relies on underditches for drainage purposes.[229] This is worth remembering in light of the changes brought on by a changing climate, since water's historical pathways in the landscape are a key to adaptation.

[227] Jordbruksmarkens värden, Jordbruksverket.se
[228] Monitor 22.
[229] Swedish Board of Agriculture, 2018.

Figure 15. Ecosystem services in the agricultural landscape.



Cultural heritage

Remains and traces in the landscape – of clearance cairns, dykes, cattle paths, terraces, stone walls, meadow barns or house foundations – reveal how it has been used over time, opening a window to the past. Pollarded trees, avenues, forage plants and animals make up our biological cultural heritage.

Fertile farmland

Agricultural land has been shaped over the course of centuries by the influence of grazing animals and humans working the land. Earthworms, microorganisms, fungi and other soil decomposers help to build up soil fertility. Clover and other nitrogen-fixing crops fertilise the soil, and fertile soils witha high peat content capture and store carbon dioxide from the air.

Recreation and tourism

The variety of agricultural landscapes is appreciated by many, offering a good quality of life and enabling tourism and other businesses to be promoted in rural areas.

Habitats

Agricultural lands and the wider landscapes offer a diversityof environments where many species thrive. Field margins, dykes, stone walls, cultivation cairns, roadsides, trees and field edges are habitats for insects, butterflies, birds, plants and game. Natural pastures and meadows are among the most species-rich type of nature we have in Sweden.

Water purification and natural water management

When water flows through soil or vegetation, unwanted substances get trapped and are broken down. A healthy soil structure helps the soil temporarily store more water for the benefit of bothgrowing crops and the surrounding area. Wetlands help to moderate water flow in the landscape and mitigate high flows.

Genetic resources

The agricultural landscape is home to domesticated animals, cultivated plants and wild species with characteristics that have been adapted so they can cope in their environment. Their genes can be important for our own future food supply, for developing new healthy and productive crops, or for developing cultivation methods that work in a changed climate.

Pest control

By benefitting ladybugs, ground beetles and spiders, which are natural enemies of pests, attacks on crops can be prevented. The use of pesticides can also be reduced this way.

Pollination

Wild pollinators like bumblebees and solitary bees, as well as honeybees, play a key role in yielding bigger, more even harvests with better quality for crops like clover seeds, apples and oilseeds. Rich, varied vegetation in fields, edges and pastures is essential for pollinators' ability to obtain a steady supply of pollen and nectar during the year.

Food production and energy

In the agricultural landscape, virtually all the food and feed is produced that animals and humans eat. In addition, agricultural products can be used for bioenergy, as a building material and much more. In addition to healthy ecosystems, active farmers are needed to supply food and energy.

The agricultural landscape and a changing climate

Like forestry, Swedish agriculture will likely be affected, both positively and negatively, by climate change. As a result of a warmer climate with an extended growing season and higher carbon dioxide levels in the atmosphere, productivity is expected to increase, and it might be necessary to grow new species that are not suitable for cultivation in our current climate.

At the same time, shifting rainfall patterns can also potentially threaten agriculture. Torrential rains are already causing damage to crops, and prolonged periods of drought like the one in the summer of 2018 are driving down production and increasing competition for water. Adapting agriculture to the new conditions is key to ensuring a reliable water supply and sustainable agriculture.[230]

Food production relies on fertile farmland, pest control and pollinators. These factors can be influenced by cultivation practices and crop selection, but a changed climate alters the conditions for both pests and pollinators as well. One climate adaptation measure that can be implemented right now for enhancing food production is to provide good habitats for both pollinators and beneficial insects near crops.[231]

At the same time, the prerequisites for preserving ecosystems directly depend on land use today and how it evolves in the future. A warmer climate that improves the conditions for agriculture has an impact on, and will be impacted by, land use. For example, measures for coping with floods as well as droughts will need to be taken. Draining the landscape and natural waterways will wipe out the conditions for the species and habitats whose distribution depends on areas that are flooded naturally. By starting with measures that leverage nature's own ability to withstand negative impacts, the agricultural landscape can be adapted to future climate change while we enhance and preserve biodiversity and supporting ecosystems.

[230] Handlingsplan för klimatanpassning, Jordbruksverkets arbete med klimat
[231] Öka skörden – gynna honungsbin och vilda pollinerare, Swedish Board of Agriculture

Examples of nature-based solutions in the agricultural landscape

Nature-based solutions in the agricultural landscape can generally be divided into two groups: one involves preserving, enhancing and regenerating wetlands, and the other entails creating variety in agriculture itself. The action of regenerating wetlands, of course, helps to create variety.

The following measures are other examples of how to create diversity in the agricultural landscape.

- Wetlands in agricultural landscapes
- Variety in agriculture:
  - Crop selection and crop diversity
  - Buffer zones
  - Biological pest control
  - Improved infiltration and no-till farming.
  - Agroforestry

WETLANDS IN AGRICULTURAL LANDSCAPES

Wetlands are capable of regulating the magnitude and frequency of flooding and can store water. Although it is often most effective to preserve and enhance existing wetlands, wetland regeneration is often the right choice in agricultural landscapes. Read more in the section on wetlands above. To best leverage a wetland's flow-regulation properties, both local and regional planning for climate adaptation are needed.

Even today, many farmers face the problem of having either too much or too little water. This affects both plant growth and animal husbandry. By regenerating or reconstructing wetlands and ponds in the landscape, these challenges can be met in a sustainable way.

CASE – Gotland

On the island of Gotland, six landowners decided to solve their water scarcity problems together.[232] Through collaboration, they built new dams and regenerated existing wetlands based on the landscape's natural hydrology. From having had water supply problems for as much as up to half the year, residents in the area noted that thanks to this measure, they had water during the entire dry season in 2016 when much of Gotland was facing a water shortage. Source: SMHI.

[232] Grannsamverkan kring grundvatten på Gotland, SMHI

A DIVERSE AGRICULTURAL LANDSCAPE

As in forestry, a greater diversity of crops, varieties and cultivation practices can represent effective nature-based solutions for addressing climate change hazards. Diversified agriculture spreads risk among different types of crops that can vary in their resilience to water scarcity or extreme weather conditions. Diverse agriculture thus not only increases resilience in the landscape as a whole, but it provides financial protection for the individual farmer if ever faced with climate-driven crop failure.[233] Several different methods are available for creating diversity in agriculture in order to boost resilience and adapt to climate change, and they can be used individually or in concert.

CROP SELECTION AND CROP DIVERSITY

Although a changed climate can put greater stress on crops that are being grown, it also enables the cultivation of new crops. Measures that spread the risks include distributing crops in a different way, changing crop rotations or increasing crop diversity. As for crops that are better adapted to a changed climate – whether new or old crops – we can look at Östergötland, where some farmers have invested in quinoa cultivation,[234] or farms on Gotland and around Örebro[235] that focus on heirloom grains.

These measures have helped to produce a diversity of crops and increase resilience, which in itself can improve resilience to pest infestation. Cultivating species that do not have a direct link to production but help to protect the harvest can also be an effective adaptation measure. This includes, for example, using different cover crops to reduce evaporation from the soil during droughts, or planting trees in order to protect the soil from wind damage.[236]

[233] Lund University, CEC Synthesis No. 4. Ekosystembaserad klimatanpassning – en kunskapsöversyn, 2017, lu.se
[234] Satsning på quinoaodling i Östergötland, SMHI
[235] Spannmål som bättre klarar ändrat klimat, SMHI
[236] Lund University, CEC Synthesis No. 4. Ekosystembaserad klimatanpassning – en kunskapsöversyn, 2017, lu.se

BUFFER ZONES

Another way to create diversity in the agricultural landscape is to use buffer zones that encourage biodiversity. Examples include the installation of buffer strips, beetle banks and shelterbelts. A buffer zone can support biodiversity and natural pest control, as well as help to protect nearby watercourses by reducing nutrient leaching from farmland.

READING TIPS

In the project "Mångfald på slätten" ("Diversity on the Plains"), the Swedish Board of Agriculture produced informational materials that offer tips and inspiration for creating more variety, and thus more resilience, in the agricultural landscape for the benefit of both farmers and biodiversity.

Beetle banks aim to benefit natural enemies and create resilience while producing other biodiversity benefits. At the Annelövs Boställe farm in Scania, beetle banks were installed to offer inspiration. The site has several demonstration farms and informational materials on creating variety in the agricultural landscape.[237]

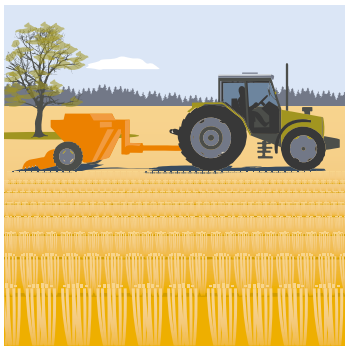
[237] Åkerlandskapet, Jordbruksverket.se

BIOLOGICAL PEST CONTROL (NEMATODES, INSECTS AND ARACHNIDS)

With biological control, pests (such as insects), weeds and plant diseases are controlled using living organisms. These organisms naturally restrict damage caused by the pest by eating, parasitising or infecting it. Biological pesticides often consist of natural pest enemies, such as nematodes, insects or arachnids. Micro-organisms, such as bacteria, viruses or fungi, can also act as biological pesticides.

Under the Swedish Ordinance (2016:402) on nematodes, insects and arachnids, the Swedish EPA provides guidance on and reviews applications for using these organisms.[238] Anyone who wishes to have a species approved can apply – growers' associations, individual growers, multiple growers submitting a joint application, or companies that sell pesticides.

IMPROVED INFILTRATION



Various types of farming methods that improve the infiltration of water into arable soil help to reduce surface runoff. Precipitation can then instead be stored in the soil and groundwater reservoirs. Because the water is detained, the pressure on ditches and streams is reduced, which in turn minimises the risk of flooding and soil erosion in downstream watercourses.[239]

There are various measures that improve infiltration.

One of these is no-till farming,[240] which is being applied at the Scanian farms of Körslätt and Charlottenslund. Other cultivation measures that improve infiltration include having a varied crop rotation, perennial crops, or reducing soil compaction by not using too heavy machinery or plowing when it is too wet.[241]

[238] Nematoder, insekter och spindeldjur (NIS) som biologiska bekämpningsmedel, naturvardsverket.se
[239] Naturanpassade åtgärder mot översvämning, lansstyrelsen.se
[240] Plöjningsfritt jordbruk som metod i ett framtida klimat, fördjupning, SMHI
[241] Jordbruksverkets strategi för hållbar hantering av vatten i jordbruket, jordbruksverket.se

AGROFORESTRY

Agroforestry is a collective term for the combination of agriculture with forestry, where trees or other perennial plants are grown and integrated with animal husbandry or crop cultivation.[242] The combination of trees, crops and animal husbandry helps to reduce erosion by keeping the trees' root system in place, minimising damage from flooding and increasing water retention capabilities.

Agroforestry also increases resilience to other climate-related challenges by ensuring that root systems get their nutrients from deeper soil layers or that legume trees can maintain soil fertility through nitrogen fixation.[243] In some agroforestry systems currently in use in Europe, trees or hedges are planted in field margins or in the field itself for purposes like wind protection. At Hånsta Gård outside Uppsala, the landowner has installed allées containing fruit, berry and nut crops on the farmland.[244] There is also a national network for exchanging experiences in agroforestry.[245]

Other agroforestry examples include combined food crop and biomass production (for example, from poplars).[246] In addition to addressing climate challenges, agroforestry often contributes to a higher level of biodiversity. This can improve the conditions for pollinators and beneficial insects on a farm while offering the advantage of sequestering carbon dioxide to a greater extent.[247]

[242] Eksvärd et al. 2016
[243] Hernández-Morcillo et al. 2018
[244] Alléodling, Agroforestry Vattholma, agroforestryvattholma.se
[245] Agroforestry i praktiken – nationell agroforestryträff, Jordbruksverket.se
[246] Torralba et al. 2016
[247] Kay et al. 2020

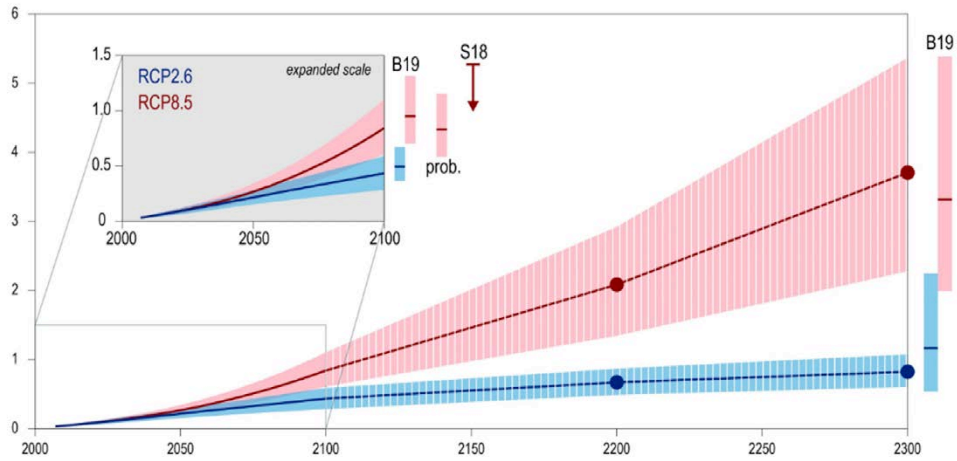
Coastal areas

Coastal areas in a changing climate

Coastal areas are unique environments shaped over time by complex and dynamic interactions among a variety of physical, ecological and socio-economic factors. Coastal areas represent a landscape that is especially vulnerable to both th rapid and slower effects of climate change. In a climate scenario with continued emissions at current levels (RCP8.5, see Figure 16), the global mean sea level is at risk of rising by slightly over 1 metre by the end of the century (baseline period 1986–2005).[248] Sea levels will also continue to rise well beyond 2100 due to climate inertia.[249] SMHI has produced projections for future mean sea levels in Swedish coastal municipalities according to different climate scenarios.[250]

An elevated mean sea level combined with temporary high water levels during storms increases the risk of flooding of buildings and infrastructure located near the sea. Furthermore, a higher sea level risks leading to increased coastal erosion[251] as well as landslides and landmass loss. The southern parts of Sweden are the areas mainly exposed to sea level rise, since the effect is counteracted by the ongoing post-glacial rebound in the northern parts of the country. Conditions for coastal erosion are mainly found in Scania, Halland, parts of Blekinge, Öland and Gotland.[252]

Figure 16. Examples of possible representative concentration pathways (RCPs) for sea level rise under different climate scenarios. Source: IPCC SROCC 2019.



[248] Special Report on the Ocean and Cryosphere in a Changing Climate, ipcc.ch
[249] Havsnivåhöjning efter 2100, SMHI
[250] Framtida medelvattenstånd, SMHI
[251] Kusterosion, PBL kunskapsbanken, National Board of Housing, Building and Planning
[252] Översikt av Sveriges stranderosion, sgu.se

Against this background, it is therefore important to establish a deeper understanding of how different land and sea-based influencing factors, both human and natural, will shape the development of the coastal landscape at different spatial scales. This knowledge will help us make informed decisions about potential solutions for reducing the coastal zone's vulnerability to climate change, while relieving environmental and socio-economic pressures.

Basically, adaptation to flooding and erosion is grounded in three main strategies: protecting the coastline, expanding it or retreating inland.[253] Both research and practical examples offer a range of possible solutions, whether engineered (grey), nature-based, or a combination of both. Traditional engineered solutions, such as levees or breakwaters, have long been the norm for protecting coastal communities, infrastructure and settlements from coastal erosion, storms and sea level rise.[254]

However, this type of safeguard can be both costly and potentially inadequate if the climate and prevailing conditions change rapidly.[255] Engineered defences can also disrupt and alter natural sediment dynamics and currents, which can increase the risk of erosion in other locations. This entails a risk of both erosion damage to coastal settlements and a negative impact on coastal ecosystems.[256]

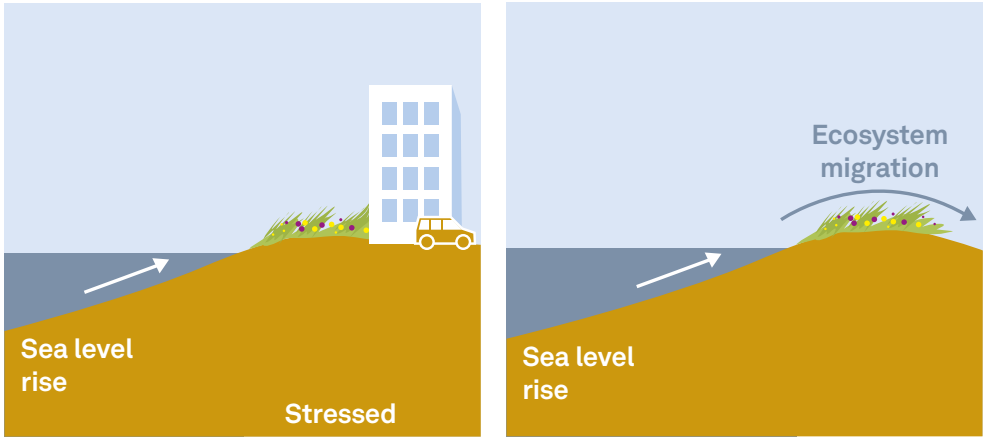
VIDEO TIPS

SMHI's website contains valuable information about rising sea levels, their consequences for Sweden and what we can do to limit the challenge. A short video summarising the challenge of rising seas is also available.

[253] Inför hotet om stigande havsnivåer: planering och design av ett föränderligt landskap, forskningsrapport, msb.se
OECD – Policy highlights responding to rising seas, oecd.org
[254] Morris et al. 2018
[255] Morris et al. 2018
[256] Arkema et al. 2017

Engineered erosion and flood safeguards for individual properties can also take up too much space and so undermine the ability to pursue nature-based solutions along a stretch of coastline.[257] Furthermore, hard defences or other fixed structures can give rise to the phenomenon known as *coastal squeeze*, whereby ecosystems in coastal environments are displaced because they cannot retreat further inland due to obstacles (see Figure 17).

Figure 17. The phenomenon of coastal squeeze. The image on the left illustrates how a coastal ecosystem (such as coastal meadows) is prevented from retreating up along the shore because of a hard barrier. The image on the right illustrates how the lack of a hard barrier allows the ecosystem to migrate up along the shore as the sea level rises.



However, a growing field of research reveals how natural habitats, such as coastal vegetation, wetlands, natural dune environments, and seagrass or eelgrass beds[258] can attenuate wave energy, add and bind sediments that counteract erosion and flooding, and reduce storm damage at temporary high water levels.[259]

As hard coastal defences like breakwaters and embankments have become less economically and environmentally defensible, arguments for restoring and creating nature-based solutions to protect the coastal landscape have grown ever stronger.[260]

For example, one study shows how salt marshes and seagrass beds can reduce wave height by 72 percent and 36 percent, respectively, compared to 30–70 percent using a lower, free-standing breakwater.[261] Coastal habitats also constitute a dynamic ecosystem that, under the right conditions, has the capacity and flexibility to adapt to new conditions. Living ecosystems are also able to rebuild themselves after facing major storms and high water levels.[262]

[257] Vilken plats biologisk mångfald får i lokalt beslutsfattande, Lomma Municipality, YouTube
[258] Case studies: Eelgrass Lommabukten Skåne – Building with Nature, buildingwithnature.eu
[259] Arkema et al. 2017; Bridges et al. 2015; Taal et al. 2016
[260] Morris et al. 2018
[261] Morris et al. 2018
[262] Morris et al. 2018; Bridges et al. 2015

Some nature-based solutions can also reduce the risk of erosion by reducing the flow energy of the eroding water and, in some cases, increase the sediment supply.[263] An increased supply of sediment built on the coast and its dune environments can in turn promote both biodiversity and recreational values, as well as reduce the risk of rock slide.[264]

Natural coastal environments often possess a unique biodiversity of species and habitats, both below and above the water's surface. By constructing, restoring, protecting and managing natural ecosystems along the coast, we can strengthen ecological relations and distribution corridors for plants and animals (green infrastructure).[265] Through green infrastructure, we reduce landscape fragmentation and make natural environments more resilient and adaptable to changes in the environment caused by both land use and a changing climate.

In many cases, nature-based solutions can be implemented in combination with hard engineered solutions.[266] Such a combination can help to reduce the stress on hard barriers and extend its service life. A clear example is how the construction of a coastal wetland or dune environment becomes a buffer zone between a hard erosion defence and the sea. In this way, the defences can relieve each other. Nature-based solutions in coastal zones also include more engineered solutions aimed at protecting the coast from hydrological and geomorphological challenges, such as storm damage, coastal erosion and landslides. Examples are bamboo fences or vegetation-covered embankments that are connected to other solutions, such as ditches.

There are, of course, limits to the capacity of nature-based solutions to protect the coastal landscape from flooding and erosion damage. Nature-based solutions, like all forms of natural or engineered grey solutions, have a threshold for powerful extremes beyond which the measure no longer provides the intended protection.[267] Furthermore, the solution can take time before it reaches its full capacity since many nature-based coastal defences require time to develop.

Even though interest in and public awareness of nature-based solutions has increased significantly in recent times, hard defences are still the main solution being planned and installed on a small scale.[268] Sweden only boasts a handful of natural erosion defences, and most of the work being done in this area is through pilot projects. But experiences from other countries, such as the United States, the Netherlands and tropical countries, show how coastal ecosystems like *coral reefs, wetlands, mangrove swamps* and *mussel beds* have provided highly effective protection during storms and floods.[269]

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[263] Sheppard, C.C. et al. 2011
[264] LIFE Coast Adapt, Vi testar nya metoder mot kusterosion, lifecoastadaptskane.se
[265] Om grön infrastruktur, Swedish EPA, naturvardsverket.se
[266] Nature-based Solutions to address global societal challenges, ucn.org
[267] Performance of Natural Infrastructure and Nature-based Measures as Coastal Risk Reduction Features, edf.org
[268] Arkema et al. 2017
[269] SGI, 2017.

In the Sand Motor project in the Netherlands, a sandbank has been created through beach nourishment. Over time, the wind, waves and ocean currents move the sand downstream of erosion-impacted stretches of coastline to provide them with sand. The site has also become a key habitat for seabirds and a popular recreational area. Source: Dutch Ministry of Infrastructure and Water Management.[270]

Nature-based protection in coastal areas varies greatly in terms of scope and design. Which solutions can be used, and how, depend on the geographical and biological site conditions. Below follow several examples of nature-based solutions for addressing coastal erosion and flooding problems.

[270] Zandmotor hompage, dezandmotor.nl

Examples of nature-based solutions in coastal environments

COASTAL VEGETATION

Coastal and near-coastal vegetation, such as sand ryegrass, salty wetlands, wooded wetlands and seagrass beds, create protection from flooding, storms and erosion. This is done through the natural processes of ecosystems, such as sediment recirculation and biomass build-up. Such processes are contributing factors in altering a coast profile, raising it relative to sea level and attenuating wave and wind power, which in turn can enhance resilience to storms, flooding and coastal erosion. For example, coastal vegetation like wetlands or seagrass beds can act as a buffer zone, reducing both wave energy and wave height as the waves pass through the dense vegetation (see the eelgrass beds example below).[271] The accumulation of sediment by vegetation can also help raise the coast profile relative to sea level, reducing the risk of flooding. Restoring and installing coastal vegetation and wetlands can thus be an alternative or complement to building levees and breakwaters.[272]

The reforestation of native species like sand ryegrass helps to re-create the coast's natural profile. Photo: Linn Carlsson, Lomma Municipality.

[271] Morris et al. 2018
[272] Lund University, CEC Synthesis No. 4. Ekosystembaserad klimatanpassning – en kunskapsöversyn, 2017, lu.se

In the coastal town of Ängelholm,[273] sand ryegrass and beach grass were planted as a nature-based solution for binding the sand together, thus reducing erosion.[274]

When taking measures that include planning plant species in coastal areas, it must be remembered that some plants can take a long time to establish themselves and provide the intended protection. Plant planning can also be disrupted by human impact, so efforts that build acceptance and raise awareness about why the measure is being carried out are crucial. A changing climate can, of course, affect plants' ability to establish themselves and thrive, which is why species that are geographically suitable for the site should be chosen. Any new species that are planted might be able to outcompete native species in the ecosystem, so they should be carefully studied before implementing the measure (see examples below).[275]

REMOVAL OF INVASIVE SPECIES AND REGENERATION OF NATURAL DUNE ENVIRONMENTS

Studies have shown how natural dune environments and sandy beaches can provide effective flood protection by providing a defence for beach-front buildings.[276] Furthermore, coastal sand dunes and sandy beaches are essential from a biological point of view because many unique species and specialised ecosystems are found in this environment. At the same time, biodiversity in these areas is under severe strain from land development and other human impacts.[277]

A common negative impact on dune environments comes from invasive species that risk taking over and displacing naturally occurring vegetation in a coastal area. This phenomenon hinders dune formation because the plants' root systems bind the sand together or prevent it from blowing around and moving freely along the coast. In addition, unwanted vegetation can become a kind of hard defence up to which the coastline erodes (see Figure 17, Coastal Squeeze).[278] This risks accelerating the coastal erosion process, and it also exposes coastal ecosystems that thrive in dune environments to threats because the specific habitat shrinks as the beach erodes.[279] Invasive species also pose a general threat to biodiversity as a result of displacement and environmental change.

[273] Åtgärds och beredskapsarbete, Ängelholm Municipality
[274] elern_von_sofie_150728, slu.se
[275] Cunniff and Schwartz, 2015
[276] Morris et al. 2017; Morris et al. 2018
[277] Lund University, CEC Synthesis No. 4. Ekosystembaserad klimatanpassning – en kunskapsöversyn, 2017, lu.se
[278] Pontee, 2013
[279] Ask an Expert – What is coastal squeeze? YouTube

Removal of invasive species in order to restore natural coastal ecosystems that promote dune formation. In several locations throughout Sweden, the possibility of removing invasive species is being tested in order to re-create open sandy areas and dune environments. This is being done both to promote biodiversity and ecosystems and to encourage dune formation to counteract coastal erosion and flood risk. Photo: LIFE Coast Adapt.

Along several of Sweden's coasts, the introduction and spread of invasive and expansive species like beach rose (*Rosa rugosa*) is giving rise to these problems. In some cases, trees have also been planted adjacent to sandy beaches to avoid sand escaping to nearby farmland. Over time, the trees have spread down towards the beach, posing a threat to the beach's ecosystem, natural dynamics and movement of the sand.[280] So to address the problem, methods are being tested in several locations that involve removing invasive species wherever dune environments should be re-created and the sand should move about more freely. By excavating or otherwise removing the invasive species, native species have the potential to become re-established. In some cases it might be necessary to replant native plant types, such as sand ryegrass or beach grass, in the dune environment.

Another option for minimising sand flight and encouraging dune formation to protect beach-front buildings is sand fencing. Although a sand fence is not a living ecosystem, it offers a way to imitate and accelerate nature's own ability to rebuild a protective dune environment. In short, sand fencing helps to hold the sand together and to influence its movements and direction so that a dune environment builds up. Such fences can also help protect existing dunes and vegetation from impact along sensitive parts of the beach.[281]

[280] Sand Life – Restaurering och skötsel av sandmark i södra Sverige
[281] Hamilton, A. 2019

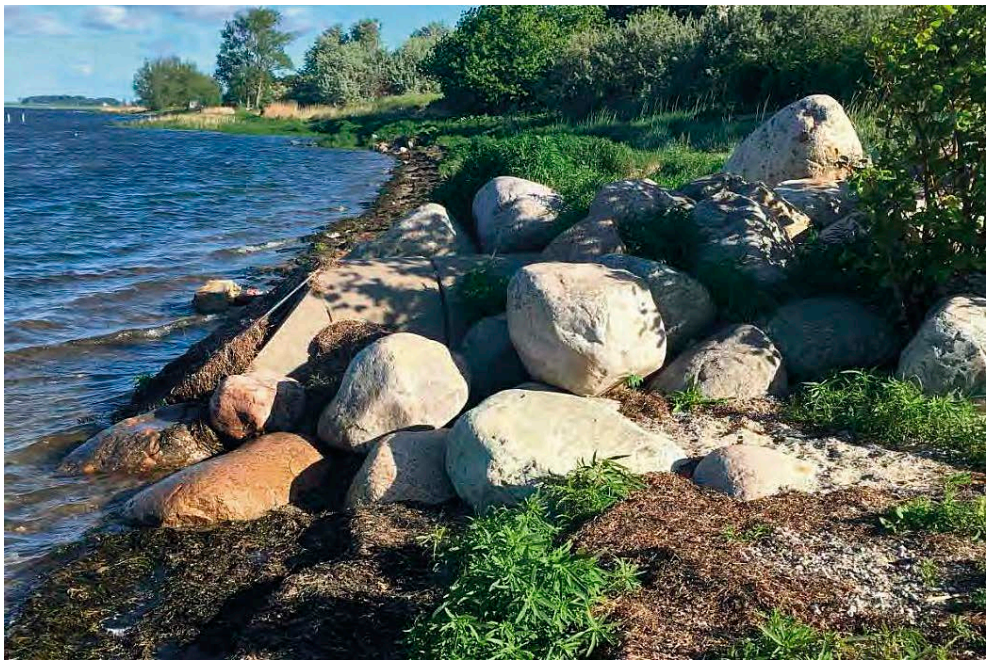
Comparison of sand accumulation and dune formation over the period 2018–2020 using sand fencing made of willow sticks at Vejbystrand in Ängelholm Municipality (pilot installation 25 metres long). Two years after implementation, significant amounts of sand had accumulated and vegetation was re-established. Photo and source: Anna Hamilton (2018) and Geraldine Thiere (2020). Illustration by GT.

All in all, dune environment restoration helps to bolster the sand's ability to protect beach-front buildings and infrastructure. It is important to carefully examine the conditions for measures along sandy beaches so that they work well over time. The volume of sand on a beach is a major factor when considering what kind of protection a sandy beach requires. Another factor to consider is that the beach must have a wide enough profile for a re-created dune environment to function in the long term.[282]

[282] Tools for sand volumes and erosion sensitivity, County Administrative Board of Scania, lansstyrelsen.se

REMOVAL OF HARD STRUCTURES

In Sweden, methods are being tested that involve removing hard structures in order to reduce erosion. These can include stone cairns, older breakwaters or old concrete pipes. In some places, these hard structures are impacting currents and wave movements in a way that erodes the sand and accelerates the erosion process around the structures. The long-term effects of the hard structures on the beach profile have not previously been well understood. Removing the hard structures offers a way to study how ocean currents can move more naturally to reduce sand flight and help restore the beach's natural profile.[283] In the Life Coast Adapt project in Scania where this method is being tested, it is being combined with other nature-based solutions such as the establishment of wetlands and the regeneration of dune environments.



Pilot project in Scania: By removing hard structures like concrete pipes, ocean currents can move naturally and less sand is washed away from the shore. This increases the coast's natural ability to withstand flooding and erosion. Photo: LIFE Coast Adapt.

PROTECTION AND REPLANTING OF EELGRASS BEDS

Eelgrass beds are a type of seagrass vegetation found on shallow seabeds along Sweden's southern coasts. They constitute a multifunctional ecosystem for both fish production and species diversity. In addition to their role as an ecosystem habitat, eelgrass beds are able to accumulate sediments and anchor them to the bottom and to buffer wave action.[284] Through its complex root system, eelgrass helps to retain sediments and stabilise seabeds, thus reducing the risk of erosion.[285]

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[283] LIFE Coast Adapt Method, Remove hard structures, lifecoastadaptskane.se

[284] Arkema et al. 2017; Lund University, CEC Synthesis No. 4. Ekosystembaserad klimatanpassning – en kunskapsöversyn, 2017, lu.se

[285] Description and guidance for the biotope "eelgrass beds" in Annex 3 to the Ordinance (1998:1252) on Protection of Areas under the Environmental Code etc., naturvardsverket.se

Furthermore, eelgrass absorbs nutrients from the water, reducing eutrophication. Large amounts of carbon are also captured and stored in eelgrass beds, which helps to curb climate change.[286]

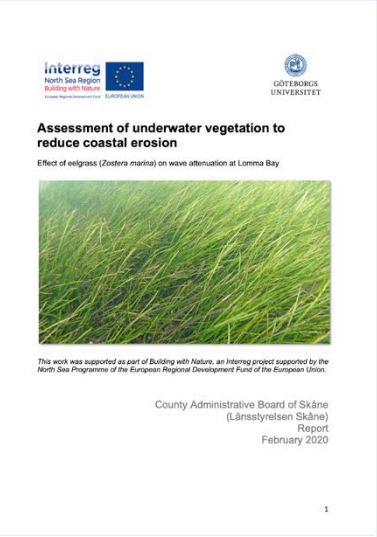
Replanting eelgrass beds as coastal protection and ecosystem restoration.
Photo: Eduardo Infantes

[286] Ålgräsängar – Arter och livsmiljöer, Swedish Agency for Marine and Water Management, havochvatten.se

CASE – Scania

Through its participation in the Interreg project Building with Nature, the County Administrative Board of Scania conducted a field study to investigate the ability of eelgrass to attenuate wave energy and reduce coastal erosion. For three months, wave and current meters took measurements in Lomma Bay at locations with both a high and a low density of eelgrass vegetation. The results showed how the wave height during a storm decreased through the eelgrass beds – about 35–40% in areas with a high vegetation density and about 5–10% in areas with a low density. Read more about the study here:

▶ Read more.


Assessment of underwater vegetation to reduce coastal erosion

Effect of eelgrass (*Zostera marina*) on wave attenuation at Lomma Bay

This work was supported as part of Building with Nature, an Interreg project supported by the North Sea Programme of the European Regional Development Fund of the European Union.

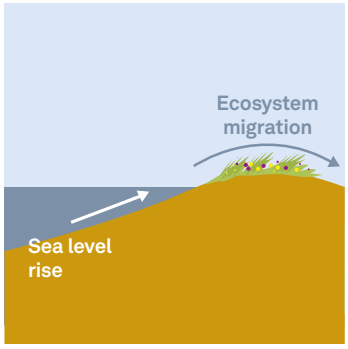
County Administrative Board of Skåne
(Länsstyrelsen Skåne)
Report
February 2020

Eelgrass beds are a globally endangered biotope whose distribution has declined sharply over the past 50 years, largely as a result of eutrophication and land development. (In Bohuslän, they have declined 60 percent since the 1980s).[287] Studies have shown that wherever large-scale loss of eelgrass has occurred, erosion has increased.[288] At present, the protection and replanting of eelgrass is therefore being investigated as a nature-based solution for protecting the coast from erosion.
A successful replanting of eelgrass beds requires special sediment and water quality conditions and the correct water temperature, light availability and salinity. The best outcomes from eelgrass planting have been achieved in places where the species has previously existed. However, studies from Sweden and other countries show that eelgrass beds show good potential for making a positive impact on sediment transport, wave attenuation and beach erosion prevention under the right conditions.[289]

The Swedish Agency for Marine and Water Management has developed a handbook for the restoration of eelgrass in Sweden containing detailed steps of the restoration process. Read the handbook.[290]

[287] Lund University, CEC Synthesis No. 4. Ekosystembaserad klimatanpassning – en kunskapsöversyn, 2017, lu.se
[288] Largescale erosion driven by intertidal eelgrass loss in an estuarine environment – ScienceDirect
[289] Assessment of underwater vegetation in reducing coastal erosion, lansstyrelsen.se
[290] Handbok för restaurering av ålgräs i Sverige – Publikationer, Data, kartor och rapporter – Swedish Agency for Marine and Water Management, havochvatten.se

ESTABLISHMENT OF ECOSYSTEM MIGRATION AREAS



By establishing "climate adaptation zones" along a stretch of coastline, the coastline can move freely inland as sea levels rise. By avoiding developments and other hard structures in a climate adaptation zone at the shoreline, it is possible to avoid squeezing valuable species and habitat types in between a rising sea level and structures like buildings, roads or hard defences.[291] Instead, space remains for the ecosystem to freely retreat up along the shore as sea levels rise. This type of measure can be ideal in coastal areas of high nature value, such as coastal meadows, and places that do not have buildings or infrastructure close to the coastline. The County Administrative Board of Scania has investigated the issue of alternative retreat zones in areas that lack or have a very low proportion of buildings or major infrastructure within 300 metres of the coastline (see Figure 18).

The study concluded that 34 percent of the total Scanian coastline lacks buildings and infrastructure within 300 metres of the coast. Such areas would thus potentially be ideal as climate adaptation zones, where the beach is left free to evolve through natural erosion processes and ecosystems are allowed to migrate upland.[292]

Figure 18. Left: Overview map of the Hagestad Nature Reserve (highlighted in red). The right-hand image shows the area's elevation profile. The calculation of shoreline decline at a sea level rise at 1 metre (based on Bruun's theory) is shown by the dashed line. The area is an uninhabited nature reserve, making it ideal as a natural retreat area of the coastline.
Source: County Administrative Board of Skåne

[291] What is coastal squeeze? – YouTube
[292] Tools for sand volumes and erosion sensitivity, County Administrative Board of Scania, lansstyrelsen.se

BEACH NOURISHMENT

Beach nourishment is a measure that reduces the negative effects of coastal erosion, and is highlighted by the Swedish Geotechnical Institute (SGI) as a natural way to restore eroded coastline.[293] With beach nourishment, sand is dug up from a suitable location in the seabed and laid out on beaches that are hard hit by erosion processes.[294] In this way, the movement of sand (the erosion process) can be enabled. Beach nourishment is a common method of addressing erosion problems in several countries, including Denmark and the Netherlands, and is also applied in Sweden.

It risks having a negative impact on biodiversity, mainly in the area on the seabed where the sediment is collected but even to some extent at the site where the sand is received.[295] It is important to make a thorough environmental impact assessment before employing this method. The demand for sand from the seabed is great, and the sand collected cannot cover all needs. An assessment should therefore also be made of whether the sand can, for example, be reused through dredging in order to avoid negatively impacting biodiversity.[296]

To protect the recipient site, it is vital to ensure that the sand does not contain any impurities or organic content, and in addition, the sand needs to be right grain size.[297] You can read more about the implementation of beach nourishment in SGI's report.[298]

Beach nourishment, Löderups strandbad, Ystad Municipality. Photo: Anders Rimne

One example is in Ystad Municipality, where sand is pumped up from the seabed at Sandhammar bank and then laid out along the municipality's most erosion-impacted beaches.[299] The purpose of the nourishment in this case is to build up the beach level so that a buffer zone is created between the waves and the fragile dunes,

[293] Erosionsskydd längs kuster och i sjöar, SGI
[294] Strandfodring. Skydd av kuster mot erosion och översvämning – SGI
[295] Lund University, CEC Synthesis No. 4. Ekosystembaserad klimatanpassning – en kunskapsöversyn, 2017, lu.se
[296] Stranderosion och stigande havsnivåer, sgu.se
[297] Fysiska och dynamiska förhållanden längs Skånes kust – underlag för klimatanpassningsåtgärder, sgu.se
[298] Strandfodring – Skydd av kuster mot översvämning och erosion, sgi.se
[299] Strandfodring i Ystad – Ystad Municipality

which in turn protect the beach-front building. The loose, dry sand is also allowed to inflate and blow up onto the dunes, further bolstering the natural coastal protection. Since the sand will erode again over time, this beach nourishment must be repeated periodically.[300]

Besides beach nourishment, another measure that can be implemented is to restore the slope of the dunes through dune restoration. Beaches that slope gently down towards the water dampen the force of the waves better than steep beaches, and are therefore more resistant to erosion.[301]

Establishing natural reefs can protect the coast from erosion while promoting biodiversity. Photo: LIFE Coast Adapt.

ESTABLISHMENT OF NATURAL REEFS

Another possible nature-based solution that can attenuate wave energy and protect the coast from erosion is the establishment of natural living reefs.

A variety of macroalgae, such as bladderwrack or serrated wrack, are a natural part of the marine biodiversity of Northern Europe. However, macroalgae have declined over the past decade and may need help to become re-established. The algae require a hard substrate, such as stone, to attach themselves to.

[300] Cunniff and Schwartz, 2015
[301] LIFE Coast Adapt, Metod – Återställa sandmiljöer, lifecoastadaptskane.se

In order to re-create the conditions for the algae to establish themselves and build up a natural reef, rock outcroppings can be put out on the seabed off the coast. The rock outcroppings on the bottom form a natural reef that reduces wave energy and protects the coastline. At the same time, they create an environment for the growth of macroalgae, which in turn constitutes a vital habitat for fish and invertebrates.[302]

This combines biodiversity promotion – by stimulating algae recovery – with coastal protection, which is provided by the living reef. This method is currently being tested and evaluated in places like Båstad Municipality as part of the LIFE Coast Adapt project.[303]

MUSSEL BEDS

Shellfish, such as oysters and mussels, are organisms that create beds that in turn can capture sediment, as well as attenuate wave energy and the erosive power of currents. Mussel beds are therefore highly capable of protecting coasts from erosion and providing a natural barrier to minimise storm damage. In several locations around the world, we can see examples of how mussel beds, both artificial and natural, help protect the coast from natural disasters.[304]

In one study, substrates from oyster shells were placed in boxes of steel wire so as not to be flushed away. The oyster larvae attached themselves to the structure and slowly began to build up a new reef structure.[305] This created a living defence against coastal erosion that improved both water purification and biodiversity, while being able to rebuild itself after a storm.[306]

Mussels do not live on sandy bottoms, but instead need some kind of structure to attach themselves to, such as an artificial coastal reef. In Sweden, however, there are currently no examples of mussel beds built as nature-based coastal erosion and flood protection.

[302] LIFE Coast Adapt | Metod, Etablera naturliga rev, lifecoastadaptskane.se

[303] LIFE Coast Adapt, Malen, lifecoastadaptskane.se

[304] Engineering with nature – an atlas, E-book, dren.mil

[305] von Elern, 2015

[306] Living Shorelines and Coastal Erosion – Oyster Restoration Workgroup, oysterrestoration.org; Factsheetsoysterreefsmusselbeds.pdf, buildingwithnatureinthecity.com

READING TIPS

Catalogue of nature-oriented erosion defences from SGI

SGI has developed a catalogue of nature-oriented erosion protection. The catalogue contains information on different solutions as well as experiences from different nature-oriented erosion defences implemented in different sites across Sweden.

- Read the catalogue.

STATENS GEOTEKNISKA INSTITUT

5

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APPENDIX 1 Nature-based solutions – a closer look

The impacts of a changing climate influence our well-being and security from an environmental, economic and social perspective. Accelerating biodiversity loss is affecting our well-being and security, too, making our communities more vulnerable. But the links between biodiversity and climate change also bring opportunities. Biodiversity can offer solutions for cutting carbon emissions and help communities adapt to climate change. Nature-based solutions (NbS) can play a key role in addressing these challenges and driving the transition to a more sustainable society.

Nature-based solutions are actions based on an ecosystem's own ability to solve the societal challenges we humans face. The starting point can thus be one or more societal challenges, and the goal is to choose a solution that provides multiple benefits or values and thus helps to solve several problems.

A nature-based solution is thus a multifunctional solution, especially compared with more traditional, impermeable (or grey) infrastructure solutions. For example, a wetland prevents downstream areas from flooding at high flows while sequestering carbon dioxide, promotes biodiversity and can be a place for outdoor recreation that brings health benefits. Investing in a nature-based solution is thus synonymous with investing in solutions to several different challenges at once.

It is important to remember that we can't know exactly what the climate of the future will be like. We can't exactly say how greenhouse gas emissions to the atmosphere will evolve over the century, or determine what type of climate change they might lead to. That's why it is vital to design our adaptation measures with a high degree of flexibility that allows for the delivery of values even if climate change does not turn out as expected. For example, a wetland can be installed to manage increased precipitation in the future. If rainfall estimates prove to be wrong, the wetland will still deliver natural water purification that reduces eutrophication in lakes and streams. The same logic can be applied to address uncertainty in models for other solutions and investments, in order to ensure that these too deliver extra value regardless of future climate change. So, nature-based solutions can be considered "no regret solutions" – solutions that, regardless of outcome, generate one or more benefits.

Definitions of nature-based solutions

There are multiple definitions of nature-based solutions from both the scientific community and organisations. There are also different names for similar solutions, where "nature-based solutions" is one term among several, such as "ecosystem-based approaches in climate adaptation" or "natural climate solution"[307] (Table 5). Some of the concepts or definitions place greater emphasis on the restoration and robust management of ecosystems, while others emphasise that nature-based solutions can also be inspired by, copied from or helped by nature.[308]

We have chosen to interpret the different definitions that exist based on the work of IUCN, CBD and the EU.

Nature-based solutions are multifunctional, cost-effective actions for addressing various societal challenges by protecting, developing or creating ecosystems while promoting biodiversity and human well-being.

The following table contains some of the different definitions and reflects the breadth of ongoing efforts around nature-based solutions.

Table 5. Different definitions of nature-based solutions.

IUCN	**Nature-based solutions** are actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits.
OECD	**Nature-based solutions** are measures that protect, sustainably manage or restore nature, with the goal of maintaining or enhancing ecosystem services to address a variety of social, environmental and economic challenges.[309]
CBD	**Ecosystem-based climate adaptation** is the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change.[310]
European Commission	**Nature-based solutions** are solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions.
Natural Climate Solutions initiative	**Natural climate solutions** are a way to reduce carbon emissions by protecting and restoring ecosystems.
Sendai Framework for Disaster Risk Reduction	**Ecosystem-based Disaster Risk Reduction (Eco-DRR)** entails combining natural resources management approaches, or the sustainable management of ecosystems, with disaster risk reduction (DRR) methods, in order to have more effective disaster prevention, reduce the impact of disasters on people and communities, and support disaster recovery.
European Commission	**Natural water retention measures (NWRM)** are multifunctional measures that aim to protect and manage water resources and address water-related challenges by restoring or maintaining ecosystems.[311]

[307] Griscom et al. 2017
[308] Naturebased solutions, European Commission, europa.eu
[309] Nature-based solutions for adapting to water-related climate risks, oecdilibrary.org
[310] Ecosystem-based Adaptation (EbA)
[311] Natural water retention measures – Environment, European Commission, europa.eu

The table makes clear that the different definitions share common features. These include measures that protect or restore ecosystems, both terrestrial and marine, and involves their better management in order to address societal challenges, such as the impacts of climate change and biodiversity loss.[312] At the same time, nature-based solutions can also explore more innovative solutions, such as mimicking how non-human organisms and communities manage extreme weather events.[313] Common to all of them is their intention to work together with nature to strengthen nature's own ability to solve problems. This means enhancing ecosystem services, whether delivered by natural ecosystems or semi-natural ones.

Nature-based solutions in relation to other key concepts

Nature-based solutions start with nature's ability to render services to use that we wish to receive, based on ecosystem services. For several years now, the concept of ecosystem services has made its way into the discussion about sustainability and urban planning. There are various tools for making ecosystem services visible and valued so that they can be included in different plans and decisions.

Another common concept nowadays is green infrastructure. Green infrastructure is a functional network of natural habitats and structures that are deployed and managed in a way that preserves biodiversity and delivers vital ecosystem services throughout the landscape. Green infrastructure contributes to the conservation of biodiversity, maintains the state of ecosystems and thus enhances key ecosystem services so as to boost the capacity for recovery from disturbances. In practice, green infrastructure efforts aim to consider conservation, protection, restoration and regeneration of habitats, ecosystem functions and natural processes during land-use planning and ongoing land and water use, as well as in the use and management of natural resources.[314]

IUCN et al.[315] believe that nature-based solutions can be considered as an umbrella term for several of the concepts that address society's challenges by using nature's own ability to deliver ecosystem services.[316]

[312] Raymond et al. 2017; Seddon et al. 2019
[313] Kabisch et al. 2017
[314] Om grön infrastruktur, Swedish EPA, naturvardsverket.se
[315] CEM work on nature-based solutions, IUCN
[316] Hansson et al. 2020

This means that the solutions are implemented in one way or another using an ecosystem-based approach and that the measures help to promote the resilience of ecosystems, meaning the resilience to change. The IUCN identifies nature conservation, management and restoration as measures for emissions reduction or climate adaptation, and points out that green infrastructure approaches are also an example of different types of nature-based solutions to meet society's needs (Figure 19).

Figure 19. Sketch of IUCN's view of nature-based solutions as linked to a variety of solutions.

It is possible to make schematic diagrams indicating which concepts are subsets of other ones, but since the different concepts have emerged from different areas of planning and management in order to address a specific challenge, there is no obvious hierarchy. The common purpose of the concepts and working practices is to help ecosystems to maintain or improve their performance of ecosystem services, thus making society more robust and resilient. Table 6 describes how the concepts relate to each other.

It is not easy to draw clear dividing lines between the different conceptualisations, nor is it fruitful. The different concepts should not be seen as competing, but rather complementary and mutually enhancing.[317] Simply put, nature-based solutions have become a way for researchers and international organisations to bring together the above approaches under a common collective term.

[317] Kabisch et al. 2017; Thoni, et al. 2017

Table 6. Comparison of four different concepts – nature-based solutions, ecosystem-based climate adaptation, green infrastructure and ecosystem services. This table expands on Kabisch et al. 2017.

Term or concept	Background	Focus	Application
Nature-based solutions	Relatively new, but highlighted during the climate summit in Paris in 2015. Stems from the work on climate adaptation and limiting climate impact.	Addressing multiple societal challenges through the same action by working with nature's own ability to solve problems. Biodiversity is often seen as central.	Umbrella term for multiple ecosystem-based approaches, which must be further developed. Initially little focus on urban planning issues.
Ecosystem-based climate adaptation	Relatively new. CBD coined the concept in 2009. Stems from efforts around climate adaptation and limiting climate impacts.	Sustainable management, conservation and ecosystem restoration for enhancing ecosystems' ability to provide protection against the adverse effects of a changing climate.	Still needs to be developed. Initially focused on land and forestry but more and more applied in conjunction with urban planning issues.
Green infrastructure	Began to be used in early 2000. Stems from EU efforts to preserve biodiversity and Govt. Bill 2013/14:141, A Swedish strategy for biodiversity and ecosystem services.	How nature's functions and qualities interrelate and are distributed over the landscape, with a focus on habitats and distribution pathways for wild plant and animal species. Aims to enhance and increase biodiversity and robust ecosystems systems that can deliver ecosystem services.	Still needs to be developed. Takes place in county board's work on developing regional guidance for green infrastructure.
Ecosystem services	Began to be used in the 1970s. Stems from work on biodiversity management.	Used to show the value that people get from nature's own work. Management of biodiversity through valuations of ecosystem services.	Relatively established concept.

Work in progress

Several different national authorities are already pursuing nature-based solutions in one way or another. However, they do not always use the term "nature-based solution" since it is relatively new. Instead, their focus can be on climate adaptation, risk reduction, ecosystem services or green infrastructure. Either way, their efforts are grounded in leveraging and enhancing nature's own ability to solve problems – working with nature.

In connection with Ordinance (2018:1428) on climate adaptation efforts by public authorities, the designated authorities have conducted climate risk and vulnerability assessments within their respective remits to find solutions to achieve the national goal for climate adaptation: to develop a sustainable and robust society for the long term that proactively addresses climate change by reducing vulnerabilities and leveraging opportunities.

Ongoing efforts around nature-based solutions for climate adaptation are presented below, as well as approaches that work together with nature to achieve set goals.

KLIMATANPASSNING.SE PLATFORM[318]

SMHI hosts this platform, which serves as a one-stop-shop for tools, guides and other aids containing examples of climate adaptation measures, including nature-based solutions. A government network for climate adaptation also exists.

COASTAL AND NEAR-SHORE AREAS

The Swedish Geotechnical Institute (SGI) has developed an overview of how erosion protection in watercourses can be designed in a nature-oriented manner.[319] SGI also plans to develop handbooks for nature-oriented erosion solutions at coastlines and for areas affected by ship-induced waves and water managment.[320]

A CATALOGUE FOR NATURE-ORIENTED EROSION PROTECTION

SGI has developed a catalogue of nature-oriented erosion protection. The catalogue contains information on different solutions as well as experiences from different nature-oriented erosion defences implemented in different sites across Sweden.[321]

REGIONAL COASTAL COLLABORATION, SCANIA AND HALLAND

This close collaborative dialogue with the coastal municipalities in Scania and Halland aims to strengthen society's ability to cope with rising sea levels.[322] The county administrative boards of Scania and Halland, SGI and the Geological Survey of Sweden (SGU) initiated this collaboration, together with municipalities and other stakeholders, to better understand and find solutions for managing beach erosion and coastal flooding.

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[318] Homepage, Klimatanpassning.se
[319] SGI 2016
[320] Stranderosion, SGI
[321] Katalog över naturanpassade erosionsskydd, SIG
[322] Scania-Halland regional coastal collaboration, swedgeo.se

LIFE COAST ADAPT

LIFE Coast Adapt is a multi-year project that aims to investigate and demonstrate various nature-based coastal erosion and flood defences while enhancing coastal biodiversity and ecosystem services. The project is funded by organisations like the EU's environmental fund LIFE and is coordinated by the County Administrative Board of Scania. In addition to the County Administrative Board of Scania, several coastal municipalities, higher education institutions and government authorities are part of the project group. The project runs during 2018–2023, and several pilot studies and sub-projects have already been carried out.[323]

BUILDING WITH NATURE

Building with Nature (BwN) is an Interreg project funded by the EU that investigates and demonstrates the potential of nature-based solutions to reduce the risk of flooding from watercourses and coastal erosion in the North Sea region. The project's overall aim is to make North Sea coasts, estuaries and catchments more adaptable and resilient to the adverse effects of climate change. Sweden is taking part in the project through the County Administrative Boards of Scania, Norway, Denmark, Scotland, Belgium, Germany and the Netherlands.[324]

REPORT: NATURE-BASED SOLUTIONS FOR FLOODING

The County Administrative Board of Västra Götaland, in partnership with the Swedish Forest Agency, has prepared a handbook on NbS measures that gives an overview of measures for detaining water in the landscape to fight climate changes like drought and flooding. The handbook describes 33 different measures that can help detain water in the landscape in a nature-oriented way.[325]

REPORT: FINANCIAL INSTRUMENTS FOR NATURE-BASED SOLUTIONS TO REDUCE RISKS OF FLOODING AND DROUGHT

This 2020 report by PE Teknik och Arkitektur, Lund University and Region Västra Götaland provides in-depth support and inspiration for valuing nature-based solutions and creating robust business models.[326]

CLIMATE ADAPTATION OF EXISTING BUILT ENVIRONMENT

The National Board of Housing, Building and Planning has published a leaflet that provides municipalities with support and inspiration in their work to adapt the existing built environment to climate change.[327] They aim to increase awareness and an understanding of the value of land permeability and to broaden the view of green infrastructure, green spaces, gaps and open spaces in cities and urban areas.

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[323] LIFE Coast Adapt website, lifecoastadaptskane.se
[324] Interreg VB North Sea Region Programme website
[325] County Administrative Board of Västra Götaland, 2018
[326] PE Teknik och Arkitektur: Financial instruments for nature-based solutions to reduce risks of flooding and drought, pe.se
[327] Mångfunktionella ytor, National Board of Housing, Building and Planning

ECOSYSTEM SERVICES

The Swedish EPA has collected information about ecosystem services on its website.[328] Website visitors can access various guides, a podcast, can become a member of an ecosystem service network and subscribe to a newsletter. A pamphlet is available that describes the arguments for ecosystem services, with statistics, studies and research showing how ecosystem services contribute to human well-being and quality of life.[329] The site also contains a guide on valuating ecosystem services as an aid in urban planning and for other purposes.[330]

The Swedish EPA has also produced a report on the integration of ecosystem services in municipal planning. The report focuses on how municipalities can integrate ecosystem-based climate adaptation in their spatial planning. Considerations include whether local planning takes into account ecosystem-based climate adaptation, how ecosystem services are used in implemented and planned measures, and how ecosystem-based climate adaptation can gain acceptance in municipal planning.[331]

The National Board of Housing, Building and Planning has produced an online guide on how to utilise and integrate ecosystem services and urban greenery when planning, building and managing the built environment in cities and towns.[332] The guidance is divided into five sections that address which ecosystem services, functions and solutions are appropriate. One of the sections specifically addresses climate adaptation, with a focus on stormwater management and temperature regulation.

The National Board of Housing, Building and Planning has developed the tool ESTER (Ecosystem Service Impact Calculation), to provide a picture of which ecosystem services are available at a location and how existing ecosystem services can be impacted by a planned measure.[333]

GREEN INFRASTRUCTURE

The Swedish EPA has produced a guide that provides a picture of how regional action plans can lay the groundwork for a greater consideration of ecosystem services and climate adaptation in spatial planning. The guidance offers examples of data and tools that can be used, as well as various analyses that can aid in prioritising actions.[334]

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[328] http://www.naturvardsverket.se/ekosystemtjanster

[329] Argument för mer ekosystemtjänster, naturvardsverket.se

[330] Guide för värdering av ekosystemtjänster, naturvardsverket.se

[331] Implementering av ekosystemtjänstbegreppet i kommunal verksamhet, Slutrapport, naturvardsverket.se

[332] Ekosystemtjänster i den byggda miljön – vägledning & metod, PBL kunskapsbanken, National Board of Housing, Building and Planning

[333] ESTER, verktyg för kartläggning av ekosystemtjänster. PBL kunskapsbanken, National Board of Housing, Building and Planning

[334] Vägledning om hur regionala handlingsplaner för grön infrastruktur kan bidra till att ekosystemtjänster och behov av klimatanpassning tillgodoses vid fysisk planering, naturvardsverket.se

THE TRANSPORT SECTOR

The Swedish Road and Transport Research Institute (VTI) has produced a report that describes a method for identifying climate-related risks for road and rail. It presents risk analyses of climate-related events and the identification and evaluation of possible measures, including a cost–benefit analysis so that planners can rank and prioritise actions.[335]

INTEGRATING ECOSYSTEM-BASED CLIMATE ADAPTATION IN MUNICIPAL OPERATIONS AND PLANNING

Researchers Christine Wamsler and Ebba Brink from Lund University have developed a process tool for municipalities with the aim of anchoring ecosystem-based climate adaptation (EbA) in relevant areas of municipal operations. The tool thus aims to create links between ecosystem service efforts with climate adaptation efforts in municipal administration.[336]

GUIDANCE FOR FLOOD MANAGEMENT RISK PLANS

In guidance from the Swedish Civil Contingencies Agency (MSB) on FMRPs according to Swedish ordinance SFS 2009:956 and MSB provision MSBFS 2013:1, MSB highlights how natural flood protection can serve as an important protection measure.[337] This can involve restoring natural flow paths, replanting of vegetation, and measures that restore natural systems to help slow flows and store water.

[335] VTI, 2019
[336] ECOSIMP tool for EbA, 2019, lu.se
[337] Report: Vägledning för riskhanteringsplaner, msb.se

APPENDIX 2 Matrix actions and benefits

Nature-based solutions in climate adaptation efforts. The matrix presents a selection of nature-based solutions and the main benefit of each measure. It also indicates whether the measure helps generate other benefits beyond the main objective and whether the benefit is low, medium or high. The table is adapted from Petsinaris et al. 2020.[338]

[338] Petsinaris et al. 2020


Economic
Social/ Cultural
Environmental
Main benefit of this solution
Co-benefit: High provision
Co-benefit: Medium provision
Co-benefit: Low provision
Increased tourism
Increased value of land/property
Income generation
Energy savings
Water provision
Food provision
Employment
Amenity value
Spiritual, religious &artistic values
Regeneration of degraded areas
Recreation, education & gathering
Health and quality of life
Carbon storage
Pollination
Biodiversity
Noise mitigation
Improved air quality
Erosion prevention
Groundwater recharge
Regulation of the water cycle
Improved water quality
Surface water flood mitigation
Green roofs
Vertical greening systems
Urban parks, forests, spaces
Greening transport infrastructure
Urban gardens
Wetland protection & restoration
Constructed wetlands
Floodplains
Restoration of streams
Re-meandering
Lake restoration
Riparian woodland
Coastal wetlands
Sand dunes
Shore & beach nourishment
Sustainable drainage systems
Rainwater harvesting
Pervious surfaces
Infiltration basins
Swales
Rain gardens
Stormwater runoff park (detention basin)
Retention ponds
Filter strips

APPENDIX 3 Applying for funding

APPLYING FOR FUNDING FOR NATURE-BASED SOLUTIONS

To apply for external funding for initiating an NbS action, there are several paths to take depending on the type of action you want to take, what the action will target, who will implement it and on what scale. The following list contains potential external funding sources.

- **LIFE – EU economic instrument for the environment**
  LIFE is an EU programme that provides financial support for environmental projects on an annual basis. Within several of its sub-programmes, you can apply for funding for climate adaptation measures and actions for enhancing biodiversity. The LIFE programmes are divided into two parts, one for the environment and one for climate action. Since NbS actions fall within the framework of both, good funding opportunities are available for this type of action. Any public or private body established in the EU can apply for a grant from LIFE as a coordinating or co-applicant beneficiary. As a rule applicants can get 55 % of their eligible costs covered, and a reasonable budget usually falls between 475,000 euros and 9.5 million. LIFE funding is therefore mainly intended for larger projects, such as intermunicipal cooperation around a catchment.

  More information about participating in a LIFE project is available on the Swedish EPA website.[339]

- **Local Nature Conservation Initiative (LONA)**
  The Local Nature Conservation Initiative (LONA) is a grant for stimulating municipal and non-profit associations' long-term commitment to nature conservation. Only Swedish municipalities can apply for LONA grants, but projects can also be initiated and run by local initiators.

  LONA grants can be obtained for up to 50 % of costs for projects that contribute to nature conservation, outdoor recreation and public health. NbS actions fall well within the scope of this grant, since NbS projects can be implemented within the grant's three areas: regular LONA, wetland LONA and LONA pollination projects.

  More information about the LONA grant and application deadlines is available on the Swedish EPA website.[340]

[339] LIFE, the EU's funding instrument for the environment, naturvardsverket.se
[340] LONA, contributions to local conservation initiatives, naturvardsverket.se

- **Local Water Conservation Projects (LOVA)**
  Local measures for a healthier marine and aquatic environment can be funded through LOVA grants. The grant can be sought from the county administrative board and is primarily for Swedish municipalities, non-profits and other types of associations.

  A LOVA grant can be used to finance NbS initiatives that help improve the environmental status of marine and aquatic environments. For example, if a measure (like wetland restoration) helps reduce eutrophication, a grant can cover up to 90 % of costs. Municipalities and non-profits can apply for a LOVA grant from the county administrative board in the county where the project will take place.

  More information about the LOVA grant and application deadlines is available on the Swedish EPA website.[341]

- **Investment grants for reducing stormwater pollutants**
  Up until 2023, the Swedish EPA is awarding grants for measures that improve the aquatic environment. Part of these grants are for investments in reducing pollutants from stormwater runoff. This can involve, for example, detention and management solutions, such as rain gardens or rain beds that both manage excessive rainfall and treat stormwater. The grant can be awarded for investments in actions, feasibility studies or preparatory measures. The grant is for public- and private-sector stakeholders, such as municipalities, wastewater utilities, property owners, associations and companies.

  Read more about stormwater treatment grants on the Swedish EPA website.[342]

- **Grants for remediation of contaminated sites to promote housing construction**
  The government has allocated annual funds for municipalities to seek grants for remediating contaminated land in preparation for housing construction. The grant is primarily aimed at remediation of pollution damage so that more homes can be built. However, it can also be sought for the remediation of nearby nature and green areas (for example, adjacent to a preschool) and can thus be used to promote the restoration of nature-based features like forest plots around planned housing units. The grant can thus be used to preserve green areas that might otherwise have been developed. Read more about grants for the remediation of contaminated land for housing construction.[343]

- **MSB – Government grant for preventive measures against natural disasters**
  If a municipality has built-up areas that face the threat of a natural disaster, low soil stability or risk of flooding, government funds can be sought to implement preventive measures. Climate adaptation funding can, of course, be sought for NbS actions aimed at preventing natural disasters. 25 million kronor has been earmarked for the 2021 fiscal year, and grants can be sought for measures that are planned or have already been implemented.

  Read more about the grant on MSB's website.[344]

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[341] LOVA – Anslag, bidrag och utlysningar. Swedish Agency for Marine and Water Management, havochvatten.se
[342] Bidrag för att minska utsläpp av mikroplaster och andra föroreningar via dagvatten 2021, naturvardsverket.se
[343] Efterbehandling av förorenad mark för att bygga bostäder, naturvardsverket.se
[344] Statsbidrag naturolyckor, msb.se

- **European Regional Development Fund**
  European territorial collaboration, also known as Interreg, entails nurturing cooperation across national borders. It aims to encourage cities and regions from different EU member states to work together and learn from each other through joint programmes, projects and networks. Here, funding can be sought for more large-scale NbS projects between regions or with several partner countries. One example is the project Building with Nature, which investigates nature-based protection against coastal erosion and flooding, whose participants include the County Administrative Board of Scania. Interreg programmes are funded by the European Regional Development Fund (ERDF).

  Read more about funding for Interreg programmes on their website.[345]

[345] EU funding, Interreg website

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Nature-based solutions

A tool for climate adaptation and other societal challenges

This report defines and explains nature-based solutions, while offering guidance on implementation together with a selection of real-world cases that demonstrate nature-based solutions in different landscape types including wetlands, urban areas, coastal areas, forests and agricultural landscapes.

The world is currently facing a double crisis – a changing climate and the accelerating loss of biodiversity. These two crises are closely interrelated and affect each other. Since nature-based solutions can simultaneously help to address both climate change and biodiversity loss, these types of solutions serve as a critical tool in climate adaptation efforts.

Nature-based solutions are multifunctional, cost-effective actions for addressing various societal challenges by protecting, developing or creating ecosystems while promoting biodiversity and human well-being. In other words, they can be used to address different types of challenges that we face. In this report, however, we have focused on how they can be used in climate adaptation efforts.

The purpose of this report is to disseminate knowledge and information about nature-based solutions and to offer guidance on how they can be planned and implemented to meet the challenges brought on by a changing climate, while promoting sustainable development through increased resilience and reduced vulnerability.

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