SEI Stockholm Environment Institute

Nature-based solutions in municipal stormwater management in Sweden

Costs, co-benefits, responsibilities and policies

SEI report
January 2025

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Published by

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Close up of a puddle of water in the city. © Niklas Storm/iStock/Getty Images Plus

Acknowledgements

This study has been financed by the Swedish Civil Contingencies Agency (MSB) and FORMAS (project "Managing vulnerabilities to water hazards in Sweden: HydroHazards"). The authors thank Aziliz Le Rouzo for her contributions to earlier versions of this paper.

DOI: https://doi.org/10.51414/sei2025.002

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Contents

Abstract

This report focuses on sustainable stormwater management in Swedish municipalities and aims to further understanding of the planning and policy context for the implementation of nature-based solutions (NbS) in Sweden. First, it investigates available cost estimates for a selection of NbS used for urban stormwater management in Sweden by scanning relevant databases and conducting a keyword search on municipal websites. Then, it maps how NbS, co-benefits, costs, division of responsibilities and policy are included in municipal stormwater documents from 29 municipalities. Finally, it explores how NbS align with regulatory and policy frameworks at the national, EU and international levels, and links co-benefits to Swedish environmental objectives, the EU Taxonomy and the Sustainable Development Goals (SDGs). The findings are intended to provide relevant stakeholders, such as Swedish municipalities, with insights into the availability of cost data for NbS, municipal steering documents for stormwater management, and an understanding of the ways in which NbS align with different policies. Limitations of the report include the absence of: stakeholder involvement, comparisons with other regional and municipal steering documents, and a thorough economic evaluation of the value of NbS and related co-benefits.

Key findings and recommendations

Findings

- Cost data for NbS, particularly for operations and maintenance (O&M), is limited.
- Most municipalities in this study have at least one steering or supporting document for stormwater management.
- NbS are recognized in the Swedish stormwater management system, though not always by the term “nature-based solutions”, and are included in municipal stormwater documents.
- Co-benefits of NbS, such as flood risk control, water quality, biodiversity, aesthetics and health, are frequently mentioned in municipal stormwater documents; other co-benefits like heat island effect, carbon sequestration, air quality, energy consumption and noise reduction are less emphasized.
- Costs are addressed only generally in municipal stormwater documents for stormwater management, highlighting the need for cost-efficient solutions and their relation to the benefits provided.
- All municipalities with at least one stormwater document recognize the importance of clarifying responsibilities for stormwater management, but the level of detail and thoroughness varies.
- Despite strong support for NbS in regulatory and policy frameworks, they often fail to fully recognize the multiple co-benefits of NbS.

Recommendations

- Support stormwater document development, and updates of existing municipal steering and supporting documents, with a focus on sustainable practices and NbS.
- Standardize cost estimates to support future implementation, operation and maintenance, and to facilitate replication by others. Consider creating reference libraries for NbS at both municipal and national levels, with a national library managed by a designated organization.
- Enhance data on operations and maintenance requirements to help municipalities plan for the long-term success of their NbS and ensure financing for both implementation and O&M.
- Broaden the focus on co-benefits to further explore the linkages between NbS for stormwater management and additional co-benefits.
- Conduct post-implementation evaluations of multifunctional NbS to assess the provision of expected co-benefits and long-term performance, allowing for adjustments and improvements.
- Clarify and establish roles and responsibilities, considering different stakeholders, stages of the NbS life cycle and varying rain intensities in the planning.
- Increase stakeholder engagement by involving external actors in both planning and implementation phases to ensure a holistic, community-driven approach.
- Recognize the multiple benefits NbS can provide in regulatory and policy frameworks, including both monetary and non-monetary value.

1. Introduction

Urban areas are expanding and densifying, while climate change is affecting precipitation patterns and continuing to drive more frequent and intense cloudburst events. These developments heighten the risk of floods leading to damage to the environment, property and societal functions (Naturvårdsverket, 2023). In cities with a combined sewer network, where both wastewater and stormwater flow through the same pipe to the wastewater treatment plant, there is a risk of overflow during heavy rainfall, leading to basement floodings and pollution of coastal areas (Semadeni-Davies et al., 2008).

Examples of these impacts are already evident in Sweden. Floodings following cloudburst events in Malmö (2014), Gävle (2021) and Jönköping (2024) have caused significant material and economic damage (SMHI, 2024; Svensk Försäkring, 2022; SVT, 2024). This reveals a need for better integration of climate adaptation measures in urban and stormwater management.

In response, the Swedish government has set two key milestones within its environmental goals framework to enhance sustainable stormwater management:

1. By 2023, all municipalities must integrate sustainable stormwater management into the planning of new buildings or significant modifications to existing structures.
2. By 2025, municipalities at risk of significant stormwater impacts on soil, water and the built environment must complete a mapping process, develop action plans for sustainable stormwater management and start implementing these plans.

To achieve these milestones, municipalities are encouraged to develop comprehensive municipal stormwater documents, such as stormwater strategies, guidelines and clear divisions of responsibility, to ensure a coordinated approach among internal and external stakeholders (Naturvårdsverket, 2023).

FACT BOX: SUSTAINABLE STORMWATER MANAGEMENT GUIDE

To support municipalities in achieving these milestones, the Swedish Environmental Protection Agency has developed a guide outlining tools, processes and methods for sustainable stormwater management. The guide outlines approaches that prevent stormwater runoff, treat polluted stormwater, enhance urban ecosystem services, and adapt to a changing climate, such as implementing nature-based solutions (Naturvårdsverket, 2023).

Sustainable stormwater management prevents stormwater runoff, treats polluted stormwater, supports urban ecosystem services and adapts to a changing climate. These goals can be achieved by implementing nature-based solutions (NbS) (Naturvårdsverket, 2023; see the fact box). NbS are multifunctional and cost-effective measures that address societal challenges by protecting, developing or creating ecosystems while promoting biodiversity and human wellbeing (Naturvårdsverket, 2021). Studies have demonstrated that green infrastructure can reduce floodings in urban

areas (Sörensen & Emilsson, 2019) and combined sewer overflow (Jean et al., 2022). However, the greening of surfaces alone does not reduce flood risk; small-scale topography is also important for flood risk reduction (Sörensen and Emilsson, 2019). The multifunctionality of NbS provides opportunities for co-benefits beyond stormwater management, such as carbon sequestration, improved air quality and energy savings.

Despite the recognized need for sustainable stormwater management, challenges remain in planning, procurement and implementation. These challenges are often social and institutional rather than technical (Cettner, 2012), and uncertainties regarding responsibilities, financing, cost data and knowledge contribute to delays in adopting sustainable systems (Qiao et al., 2018). Moreover, planning actors' perceptions of co-benefits and multifunctionality are not well understood (Hansen et al., 2019).

Against this backdrop, this report aims to address some of these challenges by:

1. Investigating available cost estimates for a selection of NbS relevant to stormwater management in Sweden.
2. Mapping how NbS, co-benefits, costs, division of responsibilities and policy are included in municipal steering and supporting documents for stormwater management in Sweden.
3. Investigating the potential policy contributions of NbS at national, EU and international levels by linking co-benefits to Swedish environmental objectives, the EU Taxonomy and Sustainable Development Goals (SDGs).

2. Methods

In this report, we focus on NbS that are used for stormwater management in urban areas in Sweden. We follow the usage of the term NbS in a report from the Swedish Environmental Protection Agency (Naturvårdsverket, 2021), recognizing that there are other terms, such as "blue-green infrastructure", that by some are considered to better describe individual solutions (Pinto et al., 2023).

To find relevant NbS, we identified solutions from Naturvårdsverket's (2021) examples of NbS in dense areas including urban greenery and green structures, wetlands, retention ponds and open stormwater systems, permeable surfaces, detention ponds, rain gardens, bioswales and two-stage ditches, and green roofs and walls. We compared and complemented these with examples of stormwater systems in *Anläggningswiki* (Facility Wiki – where information on different stormwater systems is gathered. It is hosted by VA-guiden, which is a membership service for practitioners working with water and wastewater planning, stormwater and small sewers, within municipalities, public authorities and private organizations). We excluded broad examples such as urban greenery and green structures, and merged solutions that overlapped or can be used interchangeably (for example, *växtbäddar* (rain gardens) can be used to plant various plants, from grass to trees).

Based on this review, we decided to focus on eight types of NbS:

1. Green roofs
2. Infiltration trenches
3. Permeable/porous pavements
4. Vegetated/bioswales
5. Rain gardens
6. Wetlands
7. Retention ponds
8. Detention ponds

The solutions in this list are of course not a complete list of all NbS used in Sweden, but the list provides an overview of some NbS that are frequently used. Each solution type can also be constructed differently depending on the context it is implemented in, which can affect the associated costs and co-benefits. The use of vegetation in, for example, rain gardens can affect the cost, and using trees or grass can provide different co-benefits.

Our sample includes the top 38 municipalities presented in Svensk Försäkring and IVL's ranking on climate change adaptation (Hennlock et al., 2023).

To identify cost estimates relevant to Sweden, we use data from the VISS database, SMHI's web portal *Klimatanpassning* (Climate adaptation) and *Anläggningswiki* (Facility Wiki). Additionally, we conducted a keyword search on the websites of the selected municipalities in October 2023, using various terms related to the selected NbS. The search results were then scanned for any available cost data.

To identify relevant municipal steering and supporting documents for stormwater management (also referred to as stormwater documents in this report), we began by conducting searches on municipal websites and scanning pages specifically related to stormwater management, as well as conducting a more general Google search. The goal was to identify stormwater documents that are readily accessible online; if a document could not be located through these methods, it was considered unavailable. This search was conducted in March 2024.

FACT BOX: WATER SERVICES PLAN *(VATTENTJÄNSTPLAN)*

A Water Services Plan outlines a municipality's long-term planning for public water services. It must also assess how public water and wastewater systems will be managed under increased pressure from cloudbursts (Government Offices of Sweden, 2022). For further details, refer to the explanation and guidance provided by Svenskt Vatten (Swedish Water).

A new provision, effective from 31 December 2023, mandates that each municipality must have an up-to-date Water Services Plan. This plan must contain the municipality's long-term planning of the provision of public water services and include an assessment

of water and wastewater systems management during cloudbursts (Government Offices of Sweden, 2022). However, only 23 of the 38 investigated municipalities had publicly available Water Services Plans (Table 1). To determine if and how NbS were incorporated, we reviewed available Water Services Plans (both adopted and consultation versions) from these 23 municipalities. The municipality of Sundsvall's Water Services Plan consisted of two documents, hence we scanned a total of 24 documents. As these documents generally referenced NbS only at a general level, we decided to conduct a more comprehensive assessment of the steering and supporting documents related to stormwater management.

As Table 1 shows, there are large differences between the type of steering and supporting stormwater management documentation that different municipalities have developed. These include stormwater plans, policies, strategies, guidelines, programs, stormwater plans and flood plans, as well as various combinations of all of these elements.

Steering and supporting documents for stormwater management are developed based on local needs, rather than legal requirements, to facilitate, guide and otherwise support the operations locally, internally and externally. Hence, depending on the needs, each municipality decides which documents they develop, when documents are developed, what to call them and what they contain. The purpose and content of these documents are not always fixed, and there are both clear and subtle differences between policies, strategies, plans, etc. Umbrella plans that combine multiple plans are also common. The most important aspect is that the steering and supporting documents a municipality produces (regardless of the number, format and name) are used and fulfil the intended function (N. Lans, Naturvårdsverket, personal communication, 30 September 2024).

FACT BOX: DESCRIPTION OF DIFFERENT MUNICIPAL DOCUMENTS FOR STORMWATER

There are clear and subtle differences between different municipal documents. Some municipalities, for example, Ystad and Eskilstuna, provide descriptions of their different documents:

- **Plan:** Provides specific goals and measures.
- **Policy:** Demonstrates an overall approach and provides guidance through overarching goals and values.
- **Strategy:** Forms a foundation for prioritization and describes how the municipality will achieve its goals in a specific area.
- **Guideline:** Ensures proper actions and high quality in processing and execution.
- **Program:** Shows a roadmap and describes the desired development of the organization.

Note that these descriptions are not necessarily applicable across all municipal documents.

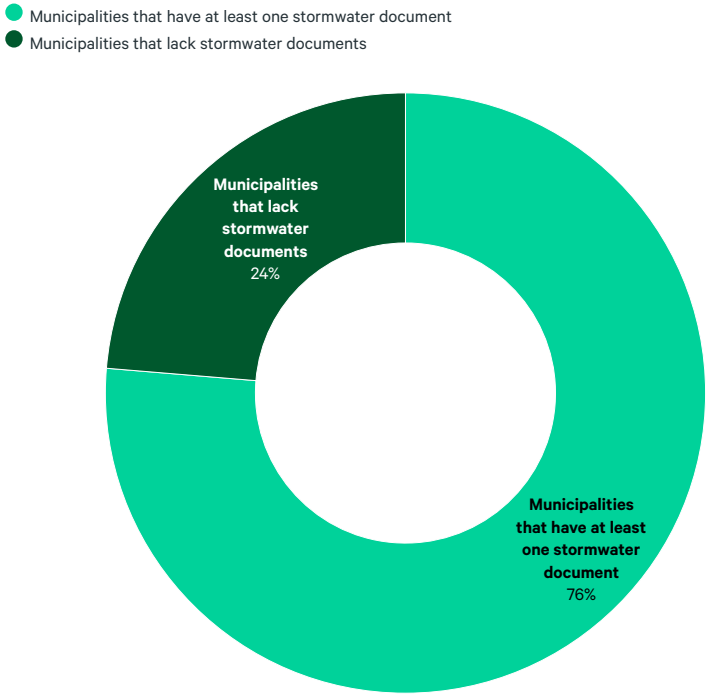
Table 1. Overview of the types of municipal documents available when the search was conducted in March 2024. The scanning consisted of 23 Water Services Plans and 48 documents for stormwater management (of which some combined e.g. stormwater guidelines and policies in the same document). Both adopted documents and consultation versions (cv)[1] were included in the scanning.

Municipality	Plan	Policy	Strategy	Guidelines	Program	Cloudburst/ Flood Plan	Water Services Plan
Norrköping	No	No	No	Yes	No	No	No
Boden	No	No	Yes	No	No	No	No
Lomma	Yes (cv)	Yes (cv)	No	No	No	Yes (cv)	No
Kristianstad	No	Yes	No	No	No	No	Yes (cv)
Gävle	No	Yes	No	No	No	No	No
Göteborg	Yes	No	No	No	No	Yes	Yes
Habo	No	No	No	No	No	No	No
Umeå	No	No	No	No	Yes	No	Yes
Helsingborg	Yes	Yes	No	No	Yes	No	Yes
Arvika	No	No	No	No	No	No	No
Linköping	No	Yes	Yes	No	No	No	Yes (cv)
Götene	No	No	No	No	No	No	Yes (cv)
Botkyrka	No	No	Yes	Yes	No	No	No
Danderyd	Yes	No	No	Yes	No	No	No
Södertälje	No	No	No	No	No	No	Yes (cv)
Lerum	No	No	Yes	No	No	No	Yes (cv)
Piteå	No	No	No	Yes	No	No	Yes
Söderhamn	No	No	Yes	No	No	No	No
Stenungsund	No	No	No	No	No	No	Yes (cv)
Lund	Yes	No	No	No	No	Yes	No
Trelleborg	No	No	No	No	No	No	Yes (cv)
Karlstad	Yes	No	No	Yes	No	No	Yes (cv)
Malmö	No	Yes	Yes	No	No	Yes	No
Västervik	No	No	Yes	Yes	No	No	Yes (cv)
Simrishamn	No	No	No	No	No	No	Yes
Stockholm	No	No	Yes	Yes	No	No	Yes (cv)
Mörbylånga	Yes	No	No	No	No	Yes	No
Västerås	Yes	Yes	No	No	No	No	No
Eskilstuna	Yes	Yes	No	No	No	No	No
Järfälla	No	No	No	Yes	No	No	Yes (cv)
Ängelholm	No	Yes	No	No	No	No	Yes (cv)
Landskrona	Yes	Yes	No	No	No	No	Yes
Sundsvall	Yes	No	No	No	No	Yes	Yes (cv)
Trosa	No	No	No	No	No	No	Yes
Täby	No	Yes	Yes	No	No	No	Yes (cv)
Vetlanda	No	No	No	No	No	No	Yes
Skara	No	Yes	No	Yes	No	No	Yes (cv)
Ystad	Yes	Yes	No	Yes	No	No	No

1 The available document was a consultation version. While it is possible that the document went on to be accepted, this accepted version of the document was not available and therefore we scanned the consultation version.

We mapped NbS, their co-benefits, and associated costs based on municipalities' stormwater management strategies, guidelines, plans and policy as well as their cloudburst and flood management plans. Of the 38 investigated municipalities, 29 had at least one specific document for stormwater management (Figure 1). In total, we scanned 48 steering or supporting documents for stormwater management, some of which combined different aspects such as stormwater guidelines and policies within a single document.

Figure 1. Number of municipalities with and without stormwater documents, as of March 2024.



The identification of co-benefits was based on categories adapted from Bozovic et al. (2017) and the Swedish Environmental Protection Agency (Naturvårdsverket, 2021). The co-benefit categories included:

1. Stormwater management
2. Flood risk control
3. Water quality
4. Carbon sequestration
5. Biodiversity
6. Heat island effect
7. Air quality
8. Aesthetics
9. Health and wellbeing
10. Energy consumption
11. Noise reduction

For the analysis, we conducted a keyword search using a list of terms related to NbS, co-benefits and cost, with iterative updates to refine the search (see final list in Appendix 1 – Keyword search). The context in which these keywords appeared was carefully considered, and any additional relevant information, such as co-benefits not covered by the predefined categories, was noted. Co-benefits were only included if they were explicitly linked to stormwater management and/or NbS. Indirect references were excluded unless specifically stated in the document (for example, a general mention of the term ecosystem services was only counted in the health and wellbeing category, unless specific examples of other co-benefits were used as examples of an ecosystem service). In addition, we mapped the explicit inclusion of multifunctionality in the stormwater documents.

We also assessed whether and how the 29 municipalities with at least one document for stormwater management included a division of responsibilities within their document(s). We also briefly assessed how these responsibilities were allocated. Finally, we investigated the inclusion of references to relevant regulatory and policy frameworks within these documents.

To identify linkages between different regulatory and policy frameworks, we started by identifying relevant frameworks for stormwater management and flood reduction from the European Environment Agency's (2021) report *Nature-based solutions in Europe: Policy, knowledge and practice for climate change adaptation and disaster risk reduction*. We summarized the described linkage between the identified relevant policy frameworks and NbS for climate adaptation and disaster risk reduction in Section 5. These were complemented by some additional frameworks, including:

1. The newly revised Wastewater Directive emphasizing that integrated urban wastewater management plans should include measures to reduce pollution from stormwater overflows and favour NbS over grey infrastructure (European Commission, 2022).
2. New developments under the EU Green Deal, and the EU Taxonomy (European Commission, 2021a), aiming to financially support necessary activities to reach the Green Deal.
3. Swedish frameworks identified from the mapping of municipal stormwater documents, including the Swedish environmental objectives, Environmental Code, Planning and Building Act and the Public Water Services Act.

Finally, we analysed links between the different co-benefits and the Swedish environmental objectives and related indicators, the EU Taxonomy objectives, and the SDGs and related targets. Only clear connections were included and the results should not be seen as a comprehensive list of all possible linkages.

3. Cost ranges

We identified cost estimates by scanning relevant databases and conducting a keyword search on the websites of the investigated municipalities. Most cost data found on the municipalities' webpages were located in consultancy reports, which often relied on other sources, previous experiences or estimates from firms. Overall, the accessibility of cost estimates is quite limited. There is a clear need for more context-specific cost data, along with transparent descriptions of what these costs include. It should be noted that this cost search was limited in scope and may have missed additional sources of cost information.

The results of our search for cost estimates in Sweden show a wide range of costs (Table 2). Costs vary depending on the context, for example whether the solution is implemented during the construction phase of a new development or in an existing built environment. Costs also depend on what is included in the calculation, such as whether the costs cover the whole structure for a green roof or only the plant layer. Factors like size, design and the intention to provide additional benefits can influence both implementation, and operation and maintenance (O&M) costs. Estimates are often uncertain when calculating the cost of an intervention, and there are few examples that provide detailed O&M costs.

These results are supported by a recent report on the costs and experiences related to the implementation, operation and maintenance of retention ponds in some Swedish municipalities, which highlights the general difficulties in obtaining cost data, particularly for O&M activities (Berglund et al., 2022). The report points to issues such as inadequate archiving and financial management practices as key reasons for these challenges.

Table 2. Identified cost ranges for different NbS.

NbS	Cost (VISS database)	Cost (search) [a]	O&M
Green roof	N/A	250–12 000 SEK (€22–1 073)/m^2	7–10 SEK (€0.60–0.90)/m^2/year
Infiltration trench	N/A	1000 SEK (€89)/m^2	3 SEK (€0.30)/m^2/year
Permeable/porous pavement	N/A	500–1860 SEK (€45–166)/m^2	27 SEK (€2.40)/m^2
Vegetated/bioswale	360 SEK (€32)/m [b]	160–10 000 SEK (€14–894)/m 160–550 SEK (€14–49)/m^3	20–35 SEK (€1.80–3.10)/m/year
Rain garden	10 000 SEK (€894)/m^2 [c]	1400–17 500 SEK (€125–1565)/m^2 3500–10 000 SEK (€313–894)/m^3	Depending on vegetation [g]
Wetland	500 SEK (€45)/m^2 [d]	120–1100 SEK (€11–98)/m^2	N/A
Retention pond	600 SEK (€54)/m^2 [e]	150–6000 SEK (€13–536)/m^2 130–1600 SEK (€12–143)/m^3	29–67 SEK (€2.60–6)/m^2/year [h]
Detention pond (dry)	700 SEK (€63)/m^3 [f]	500–950 SEK (€45–85)/m^3	3 SEK (€0.30)/m^2/year

a. Including VISS database standard costs and provided cost ranges.
b. Cost range from VISS database: 44–153%
c. Cost range from VISS database: 56–175%
d. Cost range from VISS database: 24–220%
e. Cost range from VISS database: 25–200%
f. Cost range from VISS database: 71–129%
g. O&M costs of rain gardens depend on vegetation choices: grass 9 SEK (€0.80)/m^2; bushes 34 SEK (€3)/m^2; flowers, perennials etc. 93 SEK (€8.30)/m^2; and trees 211 SEK (€19)/unit according to Edge's cost calculation tool.
h. Total cost of O&M based on calculations for a typical retention pond of 4000 m^2. Operation costs depend on the location and intention of the pond: 10.5 SEK (€0.90)/m^2 for a hidden pond without an intention to provide recreational values and 23.7 SEK (€2.10)/m^2 for a pond providing added values. Maintenance costs depend on dredging method: 320 SEK (€29)/m^2 or 16 SEK (€1.40)/m^2/year for trench dredging and 1010 SEK (€90)/m^2 or 41 SEK (€3.70)/m^2/year for suction dredging. Additional maintenance for a pond is approximately 10 000 SEK (€894)/year, for example 2.5 SEK (€0.20)/m^2/year for a pond of 4000 m^2 (Berglund et al., 2022).

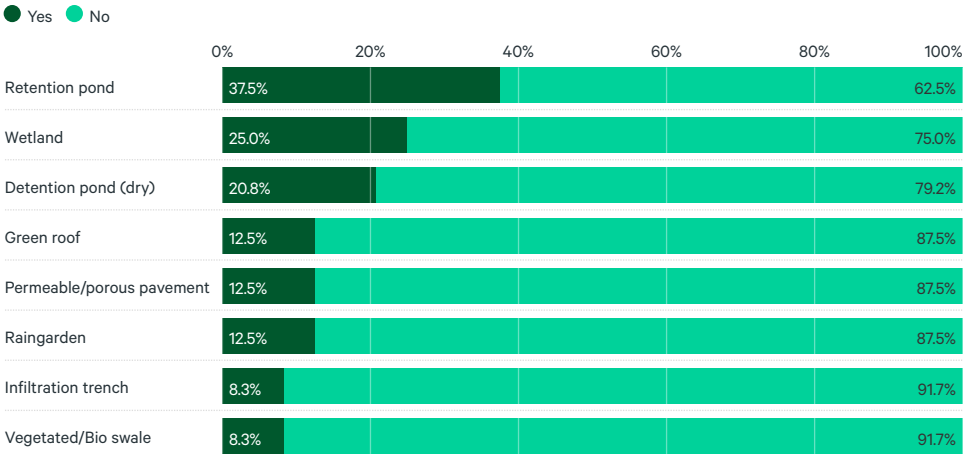
4. Municipal stormwater document mapping

This section presents the results of the analysis of NbS in the stormwater documents from the selected municipalities. The findings cover the inclusion of NbS in Water Services Plans and stormwater management documents, as well as the extent to which co-benefits, costs, divisions of responsibility, and regulatory and policy frameworks are addressed in these documents.

4.1 Nature-based solutions

All Water Services Plans include references to NbS. However, the specific term "nature-based solution" (*naturbaserade lösningar* in Swedish) is not explicitly used. Instead, terms such as "open",[2] "local", "sustainable stormwater management solutions/systems" and/or "multifunctional surfaces" are often used as proxies for NbS. However, it is important to note that these terms do not exclusively refer to NbS; for example, a multifunctional surface could also refer to a sunken playground or skateboard park. Figure 2 provides an overview of the number of Water Services Plans that mention the specific NbS investigated in this report.

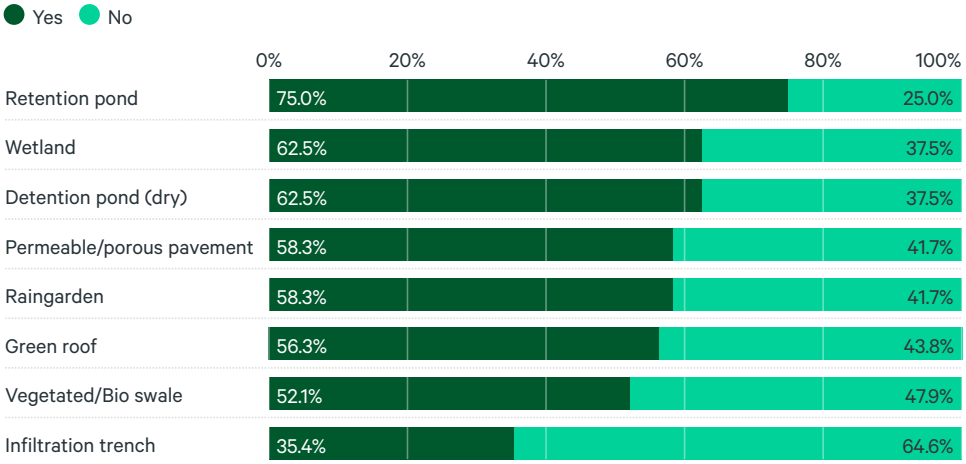
Figure 2. Number of municipal Water Services Plans that mention the specific NbS.



Similar to the Water Services Plans, the specific term "nature-based solution" is rarely used in municipal stormwater documents. However, these documents include the specific NbS mapped in this report to a greater extent, while also using similar overarching terms as the Water Services Plans (Figure 3).

2 Open stormwater management, as opposed to drainage and piping, aims to infiltrate, retain and/or store water close to the source through natural processes.

Figure 3. Number of municipal stormwater documents that mention the specific NbS.



It is clear that NbS play an integral role in stormwater management in Sweden, even though the specific term “nature-based solutions” is not widely used in these documents. Instead, terms like “open”, “local”, “green and blue”, “sustainable” and “multifunctional solutions” are highlighted as preferred approaches for managing stormwater. Municipal stormwater documents often provide examples of specific solutions, whereas Water Services Plans tend to be more general, likely due to their broader scope. Some municipalities reference their stormwater management documents within their Water Services Plans for more detailed information. This linkage was a reason for focusing on stormwater management documents in the mapping of co-benefits.

4.2 Co-benefits

The potential co-benefits provided by different NbS vary significantly. As each solution has different benefits, it is critical to identify which benefits are most desirable and how different NbS or combinations thereof can best deliver these outcomes. Table 3, which draws on valuations from the *Blågröna systemguiden* (Blue Green City Lab, 2024), illustrates the potential contribution of different NbS to various co-benefits. The intensity of contribution is represented by darker shading, indicating a stronger potential benefit. It should be noted, however, that the table provides an approximate guide rather than definitive rankings.

There is broad recognition of the added value and co-benefits provided by sustainable stormwater management. Most municipal stormwater documents (63%) specifically reference “multifunctional” solutions (*mångfunktionella* or *multifunktionella* in Swedish).

All the stormwater management documents address co-benefits, with the most frequently mentioned being **stormwater management**, **flood risk control** and **water quality** (Figure 4). An exception is found in Lund municipality’s flood plan, which notes that water treatment during rare cloudburst events is not a priority. Specific solutions linked to flood risk management mainly include wetlands, retention ponds, detention ponds and multifunctional surfaces. For water quality, a wider range of NbS is referenced.

Table 3. Adapted and based on valuations in Blue Green City Lab (2024) and complemented by VA-guiden (n.d.). The darker the green shade the higher the potential to contribute to the respective co-benefit. Grey rectangles lack data.

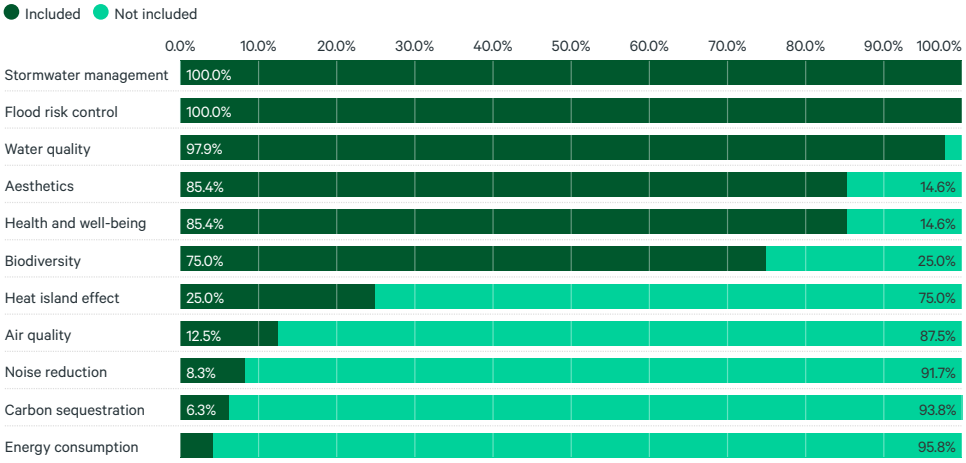
NbS/Co-benefit	Storm-water manage-ment	Flood risk control	Water quality	Carbon seques-tration	Biodiver-sity	Heat island effect	Air quality	Aesthetics	Health and wellbeing	Energy consump-tion	Noise reduction
Green roof											
Infiltration trench											
Permeable/ porous pavement											
Vegetated/ bioswale											
Rain garden											
Wetland											
Retention pond											
Detention pond (dry)											

Biodiversity, **aesthetics** and **health and wellbeing** are also commonly addressed. Many documents emphasize the positive impact of green and blue environments on urban areas. Aesthetic values are often tied to design and creating more attractive living spaces, while health and wellbeing aspects are mainly recreation and ecosystem services. Concepts such as experiences and pedagogical values, play and movement, pleasant living environments and enhanced quality of life are also highlighted in several documents.

Heat island effect is mentioned in just over one-quarter of the documents, where water and vegetation are noted for their ability to regulate temperatures and improve the local climate.

Co-benefits related to **carbon sequestration**, **air quality**, **energy consumption** and **noise reduction** receive less attention. Three municipalities address carbon sequestration: it is attributed to trees in Helsingborg's stormwater plan, and to wetlands in both Danderyd's stormwater guidelines and Mörbylånga's stormwater and cloudburst plan. Six municipalities (Gävle, Helsingborg, Danderyd, Söderhamn, Mörbylånga and Sundsvall) link air quality improvement to green areas, trees, green roofs, rain gardens, wetlands or bioswales. Energy consumption benefits are tied to reduced energy and chemical usage at waste water treatment plants (WWTPs) and pump stations (Boden's stormwater strategy), and to the high energy demands of flood damage restoration (Gävle's stormwater policy). Noise reduction is mentioned as a co-benefit in four municipalities (Umeå, Mörbylånga, Sundsvall and Gävle).

Figure 4. Coverage of different co-benefits in the analysed municipal stormwater documents.



In addition to the investigated co-benefit categories, other co-benefits mentioned in the documents include water reuse, groundwater recharge, irrigation, reduced drought impacts on food production, pollination, urban farming, preservation of natural and cultural values, insulation benefits from green roofs, improved traffic environments (for instance, rain gardens serving as speed bumps), geotechnical risk reduction and socio-economic savings from reduced flood damages.

4.3 Costs

Costs are generally discussed in broad terms, with an emphasis on ensuring that stormwater solutions in general are both environmentally friendly and cost-effective, encompassing both implementation and O&M. The documents often stress that higher costs should be justified by anticipated benefits and should account for future environmental risks and impacts.

However, most documents lack specific examples of costs associated with different stormwater systems. Notable exceptions include Eskilstuna's stormwater plan, which estimates the cost of a retention pond at 1000 SEK (€89)/m², with O&M costs of 58 SEK (€5.20)/m² annually. Helsingborg and Landskrona's stormwater policies provide a comparison between open and underground storage: Open communal storage costs approximately 150–300 SEK [€13–27]/m³ (including land costs), while underground storage beneath paved surfaces costs 1500–3000 SEK [€134–268]/m³ (excluding land costs). A few stormwater documents also suggest that open solutions can be more cost-effective than extending the pipeline network, particularly in new developments or areas undergoing densification.

Some documents call for clearer reporting of the social benefits and O&M costs of NbS during the planning phase. There is also an emphasis on the need for a clear allocation of costs for both implementation and O&M among stakeholders. These considerations should account for the multifunctionality of solutions. A few municipalities, such as Eskilstuna and Helsingborg, have included action points in their stormwater plans to

develop a reference library containing different areas, design principles, purposes, co-benefits, and cost estimates for both implementation and O&M.

The societal costs of flood damage are frequently mentioned in the municipal stormwater documents. Several documents highlight how the direct and indirect costs of flood damage often exceed the costs of preventive measures. Some references are made to the monetary costs of previous cloudburst events and estimates of what it would take to prevent similar damages. Lund's flood plan emphasizes that human safety takes precedence over financial considerations.

Lund's flood plan, Malmö's cloudburst plan and Mörbylånga's stormwater and cloudburst plan also refer to the estimated damage costs of notable cloudburst events: Copenhagen in 2011 (6–8 billion DKK, or €804.6 million–1 billion), Malmö in 2014 (over 600 million SEK, or €53.6 million), and Gävle in 2021 (over 250 million SEK, or €22.4 million). Malmö's cloudburst plan references cost estimates from the municipality of Copenhagen, which predicts that above-ground solutions to prevent cloudburst damage would cost 11 billion DKK (€1.5 billion), including 2.4 billion DKK (€321.8 million) in private investments, whereas traditional drainage solutions would cost 20 billion DKK (€2.7 billion). It also refers to Göteborg's estimates suggesting that the damage from a heavy cloudburst would cost at least 5 million SEK (€447 000), meaning that preventive measures could cost 5–10 billion SEK (€447–894 million) and still be financially viable.

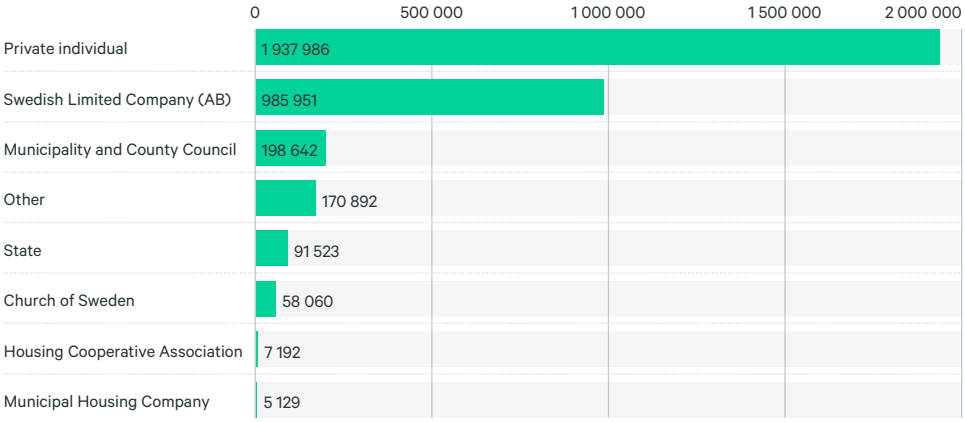
Kristianstad's stormwater policy describes how extensive embankments required to protect the city from the river could result in significant stormwater management costs. However, effective planning of stormwater solutions can reduce the need for leading or pumping the water out of the embankment. As more municipalities consider or plan embankments to protect against flooding, there is a growing incentive to prioritize sustainable stormwater management within urban areas.

4.4 Division of responsibilities

The division of responsibilities for stormwater management is complex, with no single actor holding full authority. Many different stakeholders, both within and outside municipal government, influence the overall stormwater runoff. As a result, coordinating stormwater management within municipal spatial planning is essential (Svenskt Vatten, 2016).

Municipalities typically own only a limited portion of land, while the majority is privately owned by individuals or companies (Figure 5). Within urban areas, approximately 70% of land falls under private or commercial ownership (*kvartersmark*), which could be used for local stormwater management. However, municipalities often lack the legal mandate to enforce the implementation of stormwater solutions on privately owned land. This situation creates challenges in coordinating efforts among various stakeholders (Nordlöf et al., 2023).

Figure 5. Aggregate distribution of land ownership in the 38 municipalities surveyed.



Source: SCB (https://www.statistikdatabasen.scb.se/sq/151149).

Common stormwater documents and standardized routines can enhance the integration of stormwater management across different departments and actors within the municipality. These documents help clarify the roles and expectations of both municipal bodies and external stakeholders, as recognized in the Swedish Environmental Protection Agency guidelines (Naturvårdsverket, 2023). While the internal structure of municipalities may differ, prior work in other municipalities can provide valuable guidance for developing clearer divisions of responsibility.

All 29 municipalities that have at least one document for stormwater management emphasize the importance of defining responsibilities clearly within the municipality. Important considerations identified in the documents include the division of responsibilities and associated costs between municipal departments and external stakeholders, both in different areas and at various stages of the stormwater management process. An additional layer of complexity involves the differentiation of responsibilities depending on rain intensity.

Most municipalities offer a basic description of responsibilities, typically focusing on different municipal departments. However, the responsibilities of external actors or at various stages of the process often require further clarification. Some municipalities, such as Malmö, Ystad, Västervik and Landskrona, have adopted a responsibility matrix that outlines four stages: planning, design, construction, and operation and maintenance (O&M). This matrix helps ensure that all parties are aware of their duties at each stage.

Several municipalities, including Eskilstuna, Sundsvall and Umeå, have also introduced a division of responsibilities based on different rain intensities. This distinction is crucial, since varying rain intensities result in different levels of risk and thus necessitate different strategies to prevent and manage damage.

Open and shared stormwater solutions involving multiple stakeholders may require additional clarification, particularly concerning responsibility for O&M, as well as the allocation of associated costs.

4.5 Regulatory and policy framework

Most of the stormwater documents reviewed included references to Swedish regulations and legislation that form the foundation of stormwater management, particularly in relation to water quality standards and delineation of responsibilities. Key legislative frameworks cited include the Environmental Code, the Planning and Building Act, and the Public Water Services Act. In addition, many documents refer to the EU Water Framework Directive and its associated daughter directives, such as the Groundwater Directive and the Environmental Quality Standards Directive for Priority Substances, which serve as the basis for Swedish regulations.

References to other key EU directives were also noted. These include the Floods Directive (mentioned in six documents), the Marine Strategy Framework Directive (one document) and the Freshwater Fish Directive (one document).

Approximately one-third of the documents addressed broader environmental goals at the international, national, regional or local levels. Specific mentions of the SDGs appeared in seven documents, while 15 documents referred to Sweden's national environmental objectives.

5. Link to policy frameworks

Nature-based solutions for climate change adaptation and disaster risk reduction are increasingly embedded into EU and global policy frameworks. The report *Nature-based solutions in Europe: Policy, knowledge and practice for climate change adaptation and disaster risk reduction* outlines how various policy frameworks support NbS for these purposes (European Environment Agency, 2021). Table 4 highlights some of these linkages as well as additional policy frameworks relevant to NbS for stormwater management.

Table 4. NbS links to different policy frameworks.

Framework	Description of linkage
Sustainable Development Goals (SDG)	All the SDGs incorporate climate change adaptation and disaster risk reduction, but do not explicitly refer to NbS-related terms (European Environment Agency, 2021).
United Nations Framework Convention on Climate Change (UNFCCC)	UNFCCC policy documents support the uptake of NbS for climate change adaptation and disaster risk reduction, using various NbS-related terms (European Environment Agency, 2021).
Convention on Biological Diversity (CBD)	CBD policy documents include longstanding and explicit integration of NbS, including voluntary guidelines for design and implementation of ecosystem-based approaches for climate change and disaster risk reduction (European Environment Agency, 2021).
Sendai Framework for Disaster Risk Reduction	The Sendai Framework includes clear references to climate change adaptation and disaster risk reduction and supports the uptake of NbS through related terms such as ecosystem-based approaches and management (European Environment Agency, 2021).
New Urban Agenda	The New Urban Agenda includes direct references to and promotion of the uptake of NbS and related terms in several articles (European Environment Agency, 2021).

Framework	Description of linkage
EU Water Framework Directive	While sustainable water management is a key objective of the Water Framework Directive, it does not mention NbS or their role in adaptation and risk reduction. This could, however, be explained by the fact that NbS was not a well-established concept at the time the directive was developed (European Environment Agency, 2021).
EU Floods Directive	The EU Floods Directive aims to prevent negative impacts of floodings on health, environment, cultural heritage, economic activity and infrastructure, recognizing the value of NbS to mitigate flood risks in different areas (European Environment Agency, 2021).
EU Wastewater Directive	The new revision of the Wastewater Directive recognizes urban wastewater management infrastructure to be particularly vulnerable to climate change. The directive states that integrated urban wastewater management plans should include measures to reduce pollution from stormwater overflows. Plans should also include measures to reduce pollution at the source and favour NbS over grey infrastructure according to Article 7 and 7a (European Commission, 2022).
EU Green Deal	The Green Deal language emphasizes the central role of NbS for climate adaptation and mitigation, and in ensuring healthy and resilient oceans (European Environment Agency, 2021). New developments also show its continuous support for NbS. For example, the EU Biodiversity Strategy, including the new nature restoration law, could support the uptake of restorative NbS. Similarly, the EU Adaptation Strategy promotes the use of NbS and potential co-benefits.
EU Taxonomy	The EU Taxonomy aims to support the scale-up of investments in activities necessary for reaching the EU Green Deal objectives (European Commission, n.d.). NbS are recognized as potential measures for both climate mitigation and adaptation. For example, technical criterion 4.b states that the implemented adaptation solutions "favour nature-based solutions or rely on blue or green infrastructure to the extent possible" (European Commission, 2021a).
EU Green Infrastructure Strategy	The EU Green Infrastructure Strategy includes direct references to NbS, green infrastructure and ecosystem-based approaches for climate change adaptation and risk reduction (European Environment Agency, 2021).
EU Action Plan on the Sendai Framework	The EU Action Plan on the Sendai Framework positions NbS as positive and cost-efficient measures for climate adaptation and risk reduction that also can offer co-benefits for climate mitigation, as well as human health and wellbeing (European Environment Agency, 2021).
Swedish environmental objectives	According to Naturvårdsverket (2023), related goals include: • A non-toxic environment • Thriving lakes and watercourses • Good quality groundwater • A good built environment
Swedish Environmental Code	While no references are made to NbS, Chapter 3 (6 §) of the Environmental Code emphasizes the need for green areas in and in the proximity of urban areas.
Swedish Planning and Building Act	The Planning and Building Act makes no direct reference to NbS. However, Chapter 2 (3 §) states that planning shall – considering natural and cultural values, environmental and climate aspects, as well as inter-municipal and regional conditions – promote the appropriate and aesthetic design of buildings and green spaces, long-term sustainable management of land and a good living environment for all social groups.
Swedish Public Water Services Act	The Public Water Services Act does not make any references to NbS, but it states that public water systems shall be implemented to meet requirements on the protection of human health and the environment, as well as of responsible management of natural resources in 10 §.

There are also complex interlinkages between co-benefits and different policy frameworks. For example, while the SDGs do not refer directly to NbS or related terms, there are numerous indirect relationships between SDGs and the co-benefits that NbS can provide. Table 5 illuminates these relationships by linking NbS co-benefits

to the Swedish environmental objectives, EU Taxonomy objectives and SDGs. Despite these synergies, defining and quantifying the value of co-benefits of NbS remains a challenge (European Commission, 2021b; Naturvårdsverket, 2021). There are few binding legislative frameworks that account for co-benefits when, for example, applying for funding (European Commission, 2021b). Nor does the EU Taxonomy demand substantial contributions to more than one of its six environmental objectives, leaving the challenge of recognizing the multiple benefits of NbS largely unresolved (Papari et al., 2024).

Table 5. Examples of how NbS align with the Swedish environmental objectives, EU Taxonomy and SDGs.

Co-benefit	Swedish environmental objectives		EU Taxonomy	Sustainable Development Goals (SDGs)	
	Objective	Indicator	Objective	Goal	Target
Stormwater management	4; 7; 8; 9; 10; 11; 15	4.2; 7.1; 8.2; 10.1; 11.1	2; 3; 5	6; 11; 13; 14	6.3; 13.1; 14.1
Flood risk control	7; 8; 10; 11; 15	7.1; 8.2; 10.1; 11.1	2; 3; 5	11; 13; 14	11.5; 11.b; 13.1; 14.1
Runoff quality	4; 7; 8; 9; 10; 11	4.2; 7.1; 8.2; 10.1; 11.1	3; 5	3; 6; 11; 14	3.9; 6.3; 14.1
Carbon sequestration	1; 11	1.1; 1.2; 1.3	1	13	13.2
Biodiversity/habitat creation	11; 16	11.1	6	6; 15	6.6; 15.5; 15.9
Heat island effect	15		2	3; 11; 13	11.b; 13.1
Air quality	2	2.1; 2.4	5	3; 11	3.9; 11.6
Aesthetics	15			11	11.7
Health and wellbeing	11; 15	11.1; 15.4		3; 11	3.9; 11.7
Energy consumption	15		4	7; 9; 12	7.3; 9.4
Urban noise reduction	15		5	3; 11	

6. Concluding discussion

This report has focused on the planning and policy context for the use of NbS for sustainable stormwater management in Swedish municipalities by 1) investigating available cost estimates for eight types of NbS; 2) mapping how NbS, co-benefits, costs, division of responsibilities and policy are included in municipal stormwater documents; and 3) exploring linkages between NbS and different policy frameworks.

Municipalities require support in fully integrating NbS into their existing institutional, operational and management structures (Lundy et al., 2022). While there is a growing recognition of the importance of NbS for stormwater management, a standardized example of cost data is limited. Meanwhile, appropriateness and the overall sustainability of different NbS will be context-specific and costs will depend on local circumstances, available resources, design specifics and desired co-benefits. In some areas, traditional end-of-pipe solutions may still be more appropriate.

Operation and maintenance (O&M) of NbS are critical for ensuring their long-term functionality, but there is a general need for data on O&M resource requirements of

different solutions. Although many municipalities have started incorporating O&M into their planning frameworks, there remains a data gap regarding the resources – both time and financial – needed for different NbS. Clear guidelines and examples from, for example, other municipalities could assist in better planning and more efficient allocation of O&M resources (Nordlöf et al., 2023).

Of the 38 municipalities studied, 29 had at least one stormwater document. The analysis shows that NbS have been incorporated into stormwater management strategies across all these 29 municipalities. While the term “nature-based solutions” is rarely used, the principles of NbS are clearly embedded in stormwater management documents. Measures for climate adaptation for water and sea level rise, including protection walls, could increase the risk of flooding inside these walls and can increase the requirements on sustainable stormwater management in certain areas. It should, however, be noted that NbS are not always enough to manage all cloudburst events. Here, planning of stormwater management in the larger context as well as local topography will be important (Sörensen & Emilsson, 2019).

All the municipal stormwater documents address co-benefits, and most of these documents make references to multifunctional solutions, but the coverage of different co-benefits varies. References to flood risk control and water quality as well as biodiversity, aesthetics, and health and wellbeing are generally included. However, the heat island effect, which is an important climate adaptation issue, is mentioned in only about one-fourth of the documents. Given the increasing frequency of heatwaves, both globally and in Sweden (MSB, 2015), integrating NbS for both heat management and stormwater control could provide health benefits and climate resilience.

Carbon sequestration, air quality improvement, energy consumption reduction and noise reduction co-benefits are underrepresented in the municipal stormwater documents. Energy savings, especially at wastewater treatment plants (WWTPs), could be an area of interest as NbS can reduce stormwater volumes entering the wastewater system, thereby reducing the energy demand of pump stations and at WWTPs. This aligns with upcoming regulatory pressures, such as the proposed revisions to the EU Urban Wastewater Treatment Directive, which may require WWTPs to become more energy efficient.

Cost considerations are generally addressed in broad terms, with municipalities emphasizing the importance of cost-effective solutions – also in relation to the benefits provided. However, there is limited inclusion of the specific costs associated with different NbS. As illustrated in Table 4, different NbS do not provide equal benefits across all categories. Therefore, it is crucial to carefully evaluate the expected co-benefits when designing and implementing solutions, ensuring that the chosen NbS addresses the local needs. There may also be a risk that the stormwater management dominates the implementation if performed by municipal stormwater actors, even if the initiated implementation was more holistic (Kvamsås, 2023). For private actors, understanding the broader co-benefits and avoided damage costs could incentivize investments in sustainable stormwater management (Nordlöf et al., 2023). Engagement and competence building should therefore be prioritized by both the municipality and external actors such as housing companies.

The potential for NbS to simultaneously deliver multiple co-benefits is often overlooked in traditional cost-benefit analyses. Municipalities must consider both monetary and non-monetary benefits to ensure that the full value of NbS is captured (Naturvårdsverket, 2021). Moreover, municipalities should be aware of potential trade-offs between different co-benefits. For example, enhancing flood control might conflict with aesthetic or recreational values if not properly planned. In addition, there is a lack of evaluation of implemented solutions (Naturvårdsverket, 2021). Comprehensive evaluations and post-implementation assessments are necessary to ensure long-term success and refinement of NbS strategies.

While all municipalities with at least one stormwater document recognize the importance of clarifying the division of responsibilities for stormwater management, the level of detail and thoroughness varies. Municipalities like Malmö, Ystad, Västervik and Landskrona have developed responsibility matrices that cover different phases of NbS implementation – from planning and design to construction and O&M. These models can serve as inspiration for municipalities still developing their frameworks. Open solutions shared between multiple stakeholders may require additional clarification, particularly concerning responsibility for O&M and associated costs.

The analysis also reveals strong regulatory and policy support for NbS. Despite this, regulatory and policy frameworks often fail to fully recognize the multiple co-benefits of NbS. This limits the potential to build a strong business case for their implementation (Papari et al., 2024), which could ultimately reduce the scope of NbS projects. Future studies should explore how existing policies can better support the integration of co-benefits into cost-benefit analyses and funding applications.

A key limitation of this report is the absence of stakeholder engagement and analysis of other regional and municipal steering documents. Future studies should consult stakeholders and review documents such as climate adaptation plans and urban planning policies to identify additional synergies and potential opportunities for NbS. Another limitation is that this study does not evaluate the economic feasibility of NbS. Future research should investigate alternative evaluation frameworks defining and quantifying the value of NbS co-benefits. There is also a need for further investigation into the potential risks associated with NbS implementation (Englund et al., 2022), such as the trade-off between safety (for example, drowning risks in retention ponds) and aesthetic/recreational values.

7. Recommendations

To strengthen NbS implementation:

1. **Support development of stormwater documents:** Provide continuous governmental support for ongoing municipal efforts to develop and update steering and supporting documents for stormwater management, with a focus on sustainable practices and NbS.
2. **Standardized cost estimates:** Improve and systemize the archiving of cost data to support future implementation and O&M, and facilitate replication by other municipalities. Consider creating reference libraries of implementation contexts, costs and co-benefits at both municipal and national levels, with a national library managed by a designated organization for standardizing data and updates.
3. **Enhance data on O&M requirements:** There is a need for resource estimates that can help municipalities plan for the long-term success of their NbS and ensure adequate financing for both the implementation of NbS and their ongoing O&M.
4. **Broaden the focus on co-benefits:** Further explore the linkages between NbS for stormwater management and additional co-benefits, such as carbon sequestration, heat island reduction, air quality improvement, energy savings and noise reduction.
5. **Conduct post-implementation evaluations:** Municipal and private actors should secure financing for the continuous evaluation of multifunctional NbS to verify whether they provide the expected co-benefits and meet long-term performance goals, allowing for adjustments and improvements over time. Future research should focus on evaluating implemented solutions to assess whether they deliver the expected co-benefits and value over time.
6. **Clarify and establish roles and responsibilities within municipalities:** Consider different stakeholders, stages of the NbS life cycle and varying rain intensities in the planning phase. Municipalities still defining these roles and responsibilities can learn from those who have come further along.
7. **Increase stakeholder engagement:** Enhance stakeholder engagement within municipalities by involving external actors, such as private landowners and housing companies, in both planning and implementation phases to ensure a holistic, community-driven approach to stormwater management and NbS deployment.
8. **Recognize the multiple benefits:** Regulatory and policy frameworks often fail to recognize the multiple benefits of NbS, which have a negative impact on the monetary and non-monetary value of the implementation as well as the business case. Efforts are needed at both national and EU levels to create regulations and policies that take multiple benefits into account.

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Appendix

Appendix 1. Keyword search

NbS	Co-benefits	Costs
Naturbaserad	Multifunkt*	Värde
Hållbar dagvattenhantering	Mångfunkt*	Kostnad
LOD	Mervärde	Ekonomi
Öppna	Synergi	Kostsam
Öppen	Översvämning	
Skyfallsstråk	Dagvattenhantering	
Skyfallsyt*	Rening	
Grön	Kol	
Infiltrationsstråk	Rekrea*	
Infiltrationsdike	Biologisk mångfald	
Beläggning	Ekosystem(tjänst)	
Permeabel	Värme	
Svackdike	Torka	
Växtbädd	Skugga	
Träd	Temperatur	
Regnbädd	Kyl*	
Regnrabatt	Svalk*	
Biofilter	Extrem	
Våtmark	Luft	
Damm	Estetik	
Överdämningsyt*	Gestaltning	
Översvämningsyt*	Hälsa	
	Psy*	
	Triv*	
	Pedag*	
	Lek	
	Lärande	
	Livs*	
	Social	
	Mental	
	Fysisk	
	Välmående	
	Välbefinnande	
	Energi	
	Buller	
	Ljud	

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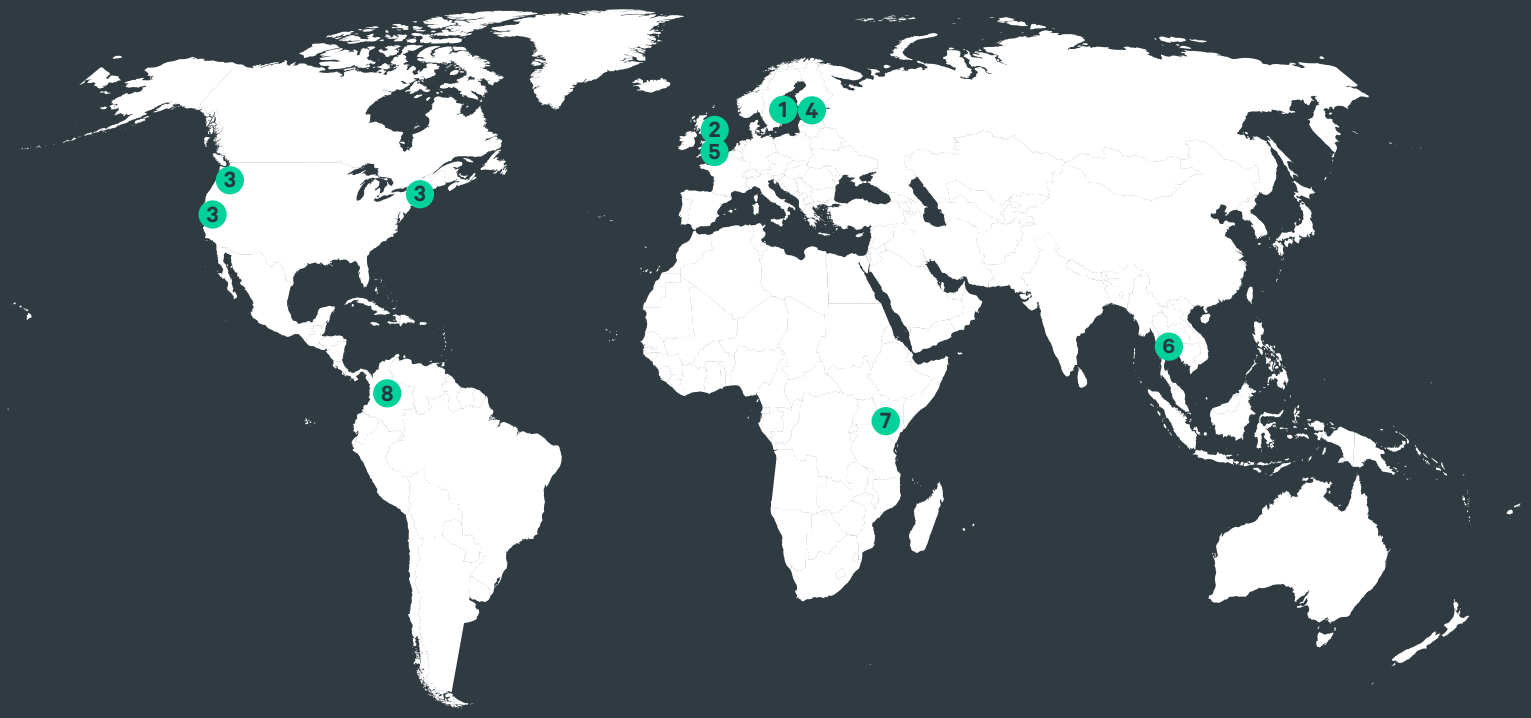

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