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LOCALIENCE

Nature-Based Solutions (NBS) in Water Retention and Sediment Management

Training syllabuses and locally adapted mutations of 3 tailored training programs D.2.2.1

Version 1

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TRAINING CONCEPT

I. Aim of the training

The training aims to empower municipalities, NGOs, and key civil stakeholders with the knowledge and skills necessary to select and implement environmentally conscious solutions for water retention and sediment management. Participants will learn how to mitigate the effects of drought, slow runoff, restore wetlands, improve damming/retention, re-naturalize watercourses, protect against erosion & landslides, and enhance ecological succession through nature-based solutions.

The textbook consists of four chapters and each is accompanied by a PPT presentation (can be adjusted based on specific needs and availability).

Understanding Nature-Based Solutions (NBS)

- Introduction to NBS: Definition, principles and benefits
- Importance of NBS in water retention and sediment management
- Case studies of successful NBS projects worldwide
- Overview of relevant policies, permissioning and other regulations, and funding opportunities

Problems and associated NBS-Interventions

- Problems that can be tackled by NBS interventions
- What is the theory of NBSs that can help in water retention and sediment management
- The relation of NBS theories in a settlement and outside in the landscape
- How certain NBS methods have multiplication and magnification impact when applying them together
- Types of Nature Based Solutions: Giving examples how an NBS look like, what is its scale, construction and limitations

Making it Happen: an NBS-Action Plan

- Guide to develop a Nature-Based Solution
- Assessment of local water retention and sediment management needs
- Action Plan: Planning and implementing NBS projects
- Addressing challenges and ensuring long-term sustainability of NBS projects

Additional Resources and Follow-up

- Manuals, guidelines and case studies on NBS in water retention and sediment management
- Encourage ongoing knowledge-sharing and collaboration among participants through online platforms or community-based initiatives

II. Practical training framework

The training is divided into a theoretical part and a practical part.

Theoretical Part - Lecture

The first two chapters (1. Understanding Nature-Based Solutions (NBS) and 2. Problems and associated NBS-interventions) form the theory and are presented using the PowerPoint presentations. Necessary equipment for the presentation and a suitable room are required. It is important to ensure sufficient breaks and variety. Of course, these parts can be made more varied with short discussions or exchanges of experiences.

Practical Part - Interactive NBS Action Plan

The third chapter (3. Making it happen: an NBS-Action Plan) represents an interactive part. This is briefly opened by a theoretical unit (3.1. Developing a Nature-Based Solution (NBS) project), i.e., a lecture using PowerPoint presentations, but then transitions into an interactive part, either all together or in small groups depending on the group size:

- Assessment of local water retention and sediment management needs

  Required Materials: Local maps, aerial photos, if available hazard zone plans, slope water maps, and sticky notes

- Action Plan

  Based on the previously identified needs/problems and the knowledge of Nature-Based Solutions (NBS) gained in the previous chapters, an action plan will be designed. Depending on local conditions (small community, large region) or time constraints (duration of the training), two variants can be implemented (for details see 3.3. Action Plan):

  - Variant 1: Local walk

    Required Materials: Map for walking route, catalogue of NBS from Chapter 2 (textbook or PowerPoint slides), camera, and notebook for documentation

  - Variant 2: Study map/aerial photo

    Required Materials: Maps, aerial photos or hazard zone plans, catalogue of NBS from Chapter 2 (textbook or PowerPoint slides), sticky notes for documentation

The collection of extra material contained in the annex (VII Annexes - Additional Resources) is not intended to be presented separately. This can be given to the participants as input during the interactive part or made available as a collection of information for breaks or after the training.

Training time / participants

The necessary time depends somewhat on the local conditions, but it is suggested that half a day for the theoretical part and half a day for the practical part, thus the training can be carried out in one day. If more detail is needed, or the development of the action plan is to be followed in detail or made for a larger area, it can of course also be extended to a 2-day event.

Possible involved stakeholders and participants include all actors affected by NBS: politicians, public agencies, scientists, institutions, experts, communities, Non-Governmental Organisations, landowners, developers, firms, and more.

The number of participants is strongly dependent on the spatial and personnel resources. In principle, the training can be carried out by a small group to over 100 people. It must be ensured for the interactive part that this is worked on in small groups of a maximum of ~8 participants and that there is also enough supervisory staff available. Especially with the variant with the local walks (3.3.1. Variant 1: Local walk), the group sizes must be adapted to the possible accompanying persons.

III. Methodological guidelines

The trainers conducting the training should have a broad knowledge of Nature-Based Solutions (NBS). Given the wide range of NBS, it is clear that there is no expert for every type of NBS. For this training, overview and big-picture knowledge is more important than detailed expertise. Suitable trainers are therefore most likely to be found in the public sector of water management or in offices that are entrusted with different NBS projects. In addition, the trainer should have experience in training and workshops, i.e. be trained in presentation techniques and communication.

If the number of participants is large, it is also recommended to organise a team of trainers to supervise the small groups and to bring in expertise from different areas. This will ensure that all participants receive adequate attention and benefit from a wide range of knowledge and experience.

The trainer should, of course, familiarise himself/herself in detail with the materials (textbook and PowerPoints). It is recommended to adapt certain parts of the PowerPoints to local conditions, e.g. to include local case studies. At the same time, the theoretical content should not be deviated from too much and the training concept should be maintained despite local adaptations.

For each training, both the participants and the organisers of the training should fill in the evaluation forms provided and document them together with a list of participants. This will ensure that feedback is collected and improvements can be made for future sessions.

IV. Training content

No.	Subject	Number of pages	Number of slides	Duration (app., in hours)
1.	Understanding Nature-Based Solutions (NBS)	14	29	1h
2.	Problems and associated NBS-Interventions	65	113	2-3h
3.	Making it Happen: an NBS-Action Plan	7	25	4h
	Total:	86	167	7-8h

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Colleague 1	
Colleague 2	

VI. Detailed training material

1. Understanding Nature-Based Solutions (NBS)

1.1. Introduction

Extreme weather events such as heavy rainfall, storms and prolonged periods of drought are already occurring in Europe and may become more frequent and increasingly intensive in the future due to climate change (Figure 1)[1]. This presents an increased risk of natural disasters with negative impacts on human life, infrastructure and environment. An extreme weather event such as intense rainfall may cause flooding of houses, fields and infrastructure. It may also cause soil erosion leading to sediment in watercourses, muddy flooding of settlements or landslides.

The negative impact of extreme weather events and the severity and increasing cost of disasters can be prevented or at least mitigated by improved planning and disaster management. For this, an assessment of water retention and sediment management needs within the local community is essential.

Implementing nature-based solutions (NBS) can enhance community resilience to extreme weather events. However, NBS are not yet widely adopted as a complement or alternative to traditional grey infrastructure solutions. There are two main obstacles to adoption. Firstly, the public lacks support, likely due to a lack of understanding of the many benefits that can be achieved. Secondly, there is a high level of risk aversion to challenging the status quo, which is partly due to gaps in data and prior experience regarding long-term cost-effectiveness[2].

This training aims to address these challenges and promote the implementation of nature-based solutions.

[1] Bednar-Friedl, B., R. Biesbroek, D.N. Schmidt, P. Alexander, K.Y. Børsheim, J. Carnicer, E. Georgopoulou, M. Haasnoot, G. Le Cozannet, P. Lionello, O. Lipka, C. Möllmann, V. Muccione, T. Mustonen, D. Piepenburg, and L. Whitmarsh, 2022: Europe. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 1817–1927, doi:10.1017/9781009325844.015

[2] European Commission, Directorate-General for Research and Innovation, Naumann, S., Burgos Cuevas, N., Davies, C. et al., *Harnessing the power of collaboration for nature-based solutions – New ideas and insights for local decision-makers*, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2777/954370

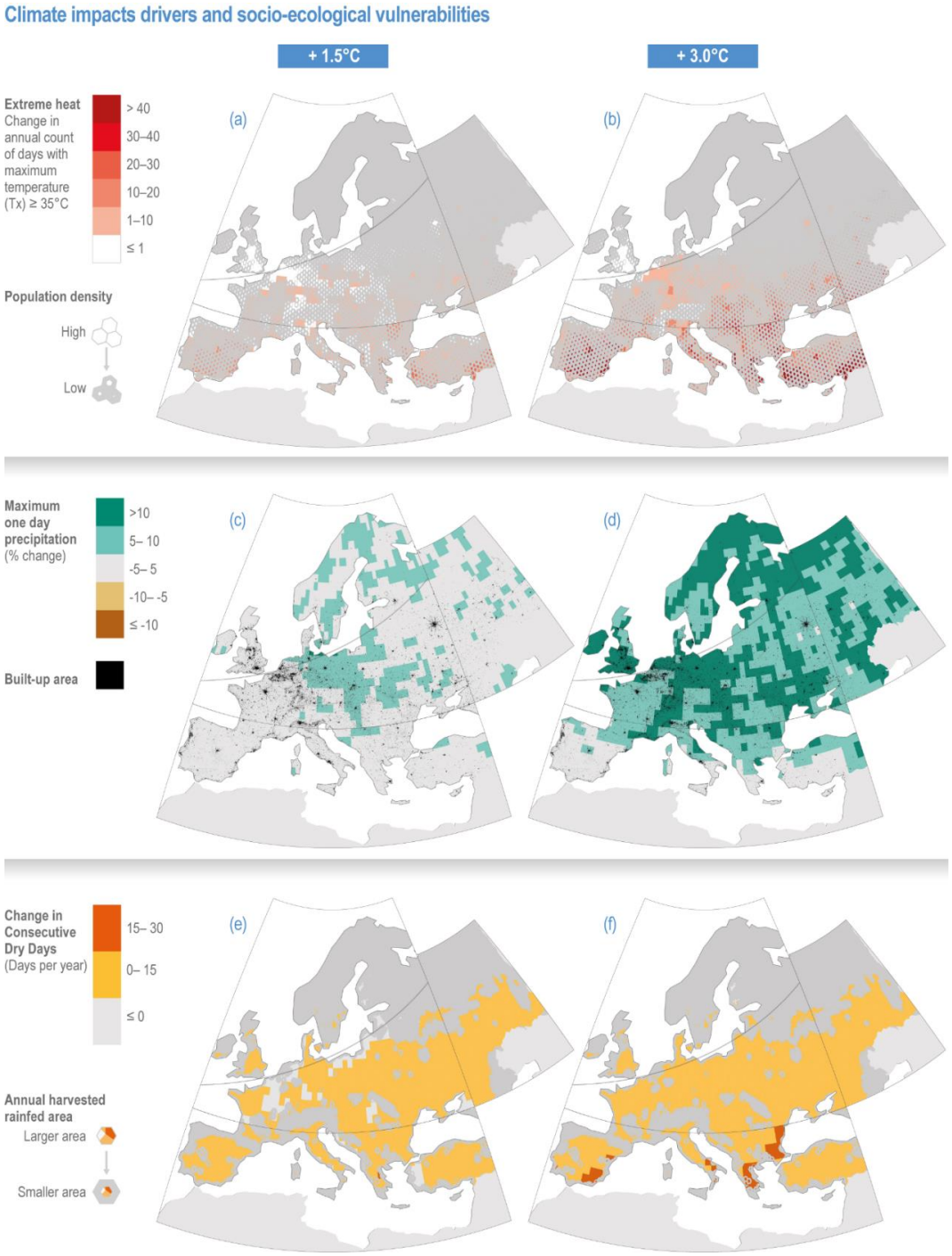


Figure 1: Changes in climate hazards for global warming levels of 1.5°C and 3°C based on the CMIP6 ensemble with respect to the baseline period 1995-2014, combined with information on present exposure or vulnerability: (a,b) number of days with temperature maximum above 35°C (TX35) and population density; (c,d) daily precipitation maximum (R × 1 d) and built-up area; (e,f) consecutive dry days and annual harvested rain-fed area[3].

[3] Figure 13.4a-f in Bednar-Friedl, B., R. Biesbroek, D.N. Schmidt, P. Alexander, K.Y. Børsheim, J. Carnicer, E. Georgopoulou, M. Haasnoot, G. Le Cozannet, P. Lionello, O. Lipka, C. Möllmann, V. Muccione, T. Mustonen, D. Piepenburg, and L. Whitmarsh, 2022: Europe. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 1817–1927, doi:10.1017/9781009325844.015.

1.2. NBS: Definition, principles, and benefits

The European Commission defines NBS as *"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."*[4]

This means NBS can be seen as projects that contribute to sustainable development by having people work with nature to overcome societal challenges. By protecting, restoring and managing existing ecosystems or creating new ones, people and nature together can produce ecosystem services that benefit society and nature at the same time (Figure 2).

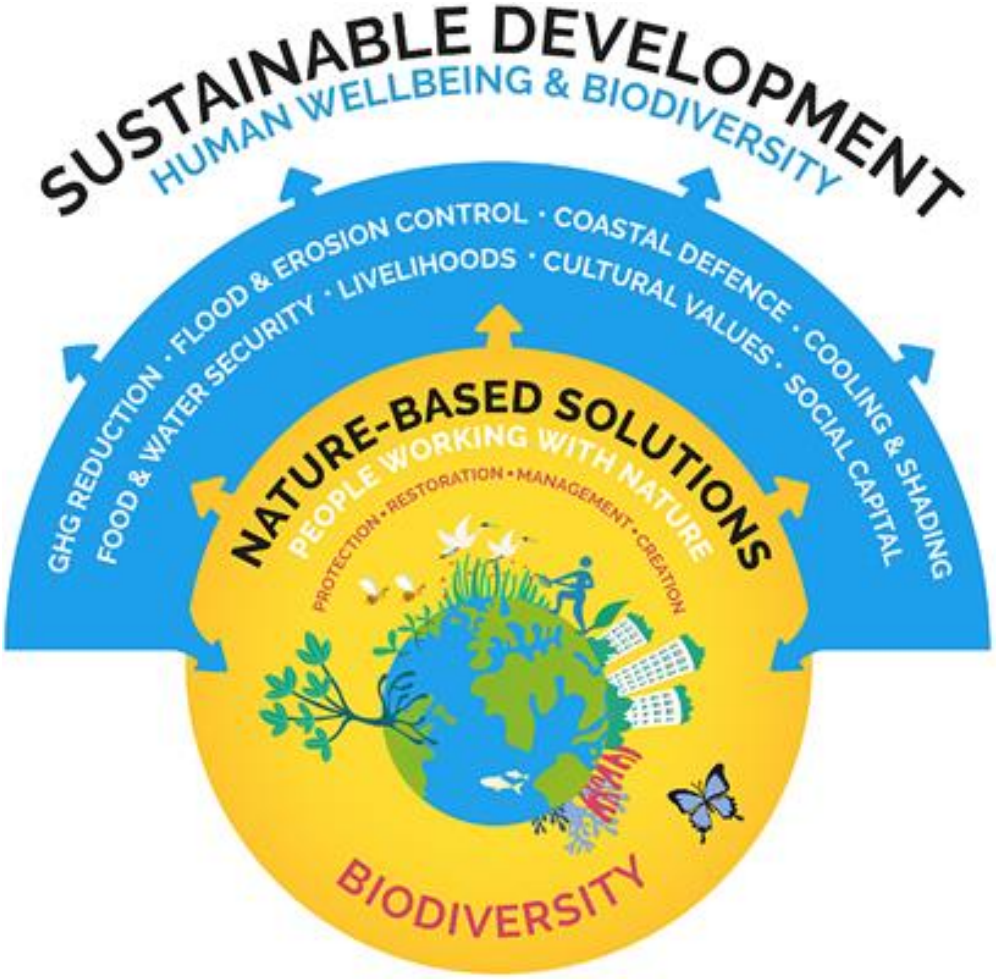


Figure 2: Conceptual diagram of the NBS principle[5] .

[4] https://research-and-innovation.ec.europa.eu/research-area/environment/nature-based-solutions_en

[5] Seddon, N., Smith, A., Smith, P., Key, I., Chausson, A., Girardin, C., House, J., Srivastava, S. and Turner, B. (2021), Getting the message right on nature-based solutions to climate change. Glob. Change Biol., 27: 1518-1546. https://doi.org/10.1111/gcb.15513

Four principal goals have been identified by the Horizon 2020 Expert Group on 'Nature-Based Solutions and Re-Naturing Cities' that can be addressed by nature-based solutions[6]:

– Enhancing sustainable urbanisation through nature-based solutions can stimulate economic growth as well as improving the environment, making cities more attractive, and enhancing human well-being.

– Restoring degraded ecosystems using nature-based solutions can improve the resilience of ecosystems, enabling them to deliver vital ecosystem services and also to meet other societal challenges.

– Developing climate change adaptation and mitigation using nature-based solutions can provide more resilient responses and enhance the storage of carbon.

– Improving risk management and resilience using nature-based solutions can lead to greater benefits than conventional methods and offer synergies in reducing multiple risks.

A key strength of NBS is that they can often address several societal challenges such as climate resilience, disaster risk reduction, water management, food security, biodiversity, human health and well-being and economic and social development. As NBS are providing sustainable management actions inspired by nature, which will benefit both people and nature at the same time, they can often bring other benefits than the main benefit of their intended purpose[7].

An example of how NBS can deal with multiple hazards and create multiple benefits at the same time, is how installing a sustainable drainage system including plants or trees in an urban setting helps manage excess water during rainstorms, thereby reducing flood risk and water pollution. In addition, it can also help create habitat, biodiversity and recreational areas and provide shade and reduce heat in the city.

It is however important to carefully design NBS to avoid trade-offs between these different goals/benefits and between stakeholders.

As NBS provide integrated, multifunctional approaches to mitigate the effects of extreme weather events and their possible risks, the contribution of several stakeholders are needed for a successful

[6] European Commission, Directorate-General for Research and Innovation, *Towards an EU research and innovation policy agenda for nature-based solutions & re-naturing cities – Final report of the Horizon 2020 expert group on 'Nature-based solutions and re-naturing cities' – (full version)*, Publications Office, 2015, https://data.europa.eu/doi/10.2777/479582

[7] Sowińska-Świerkosz, B., & García, J. (2022). What are Nature-based solutions (NBS)? Setting core ideas for concept clarification. *Nature-Based Solutions*, *2*, 100009.

implementation, and it should be seen as a task involving the entire community[8], which also supports the ability of the local community to adapt to change.

NBS has emerged as an alternative or complementary approach to more traditional engineered solutions (often referred to as "grey infrastructure") such as pipes, ditches, dams and retention basins. However, NBS will often be implemented alongside traditional infrastructure, especially in urban environments, to build resilience against e.g. climate related hazards (Figure 4)[9].

It is important to monitor and re-evaluate NBS over time through adaptive management and inclusive decision-making (Figure 3), to ensure their efficiency also through changing climate conditions[10].

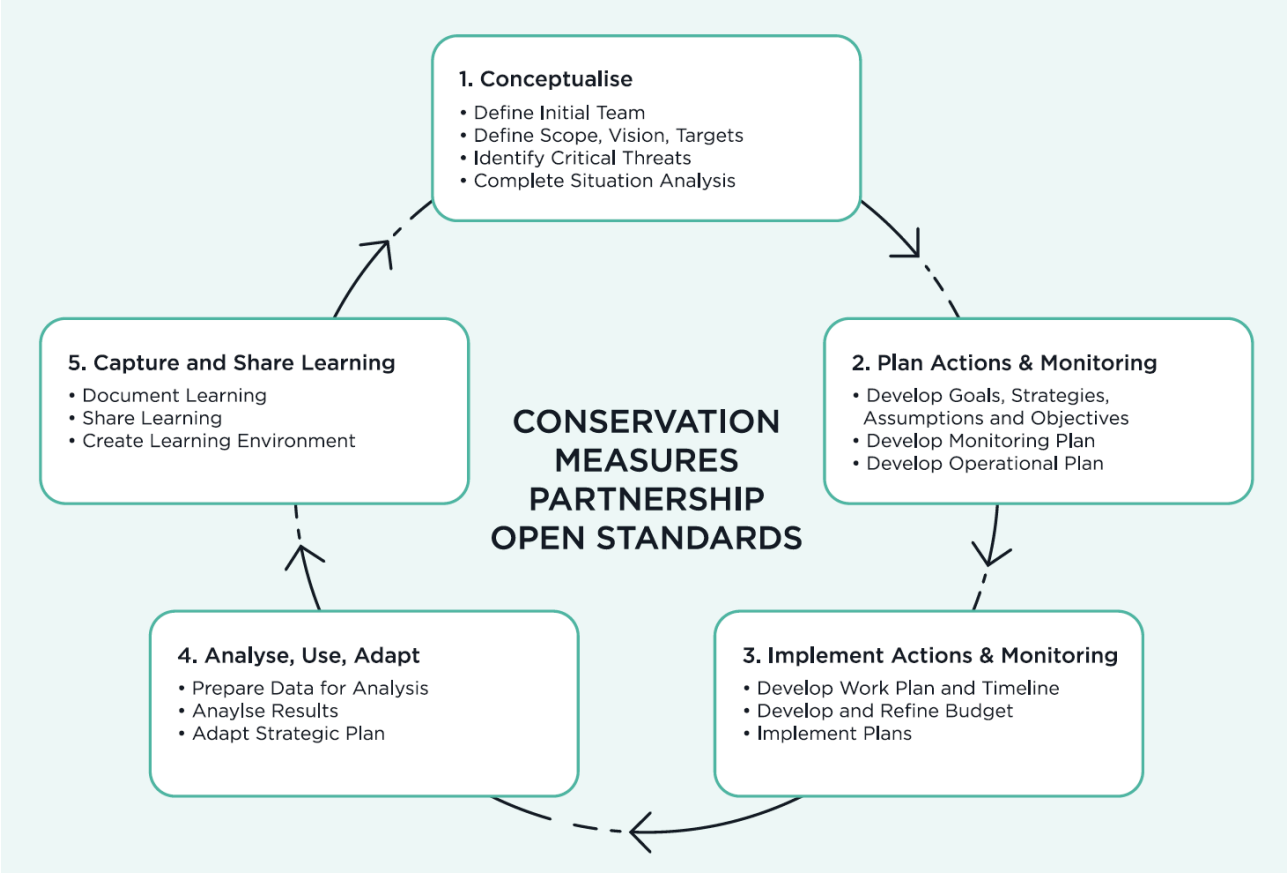


Figure 3: The adaptive management cycle[11]

[8] Seibert, S.P., Auerswald, K. (2020). Grundlagen der Abflussentstehung, Sturzfluten und dezentralen Hochwasserschutzmaßnahmen. In: Hochwasserminderung im ländlichen Raum. Springer Spektrum, Berlin, Heidelberg. https://doi.org/10.1007/978-3-662-61033-6_2

[9] Sowińska-Świerkosz, B., & García, J. (2022). What are Nature-based solutions (NBS)? Setting core ideas for concept clarification. *Nature-Based Solutions*, 2, 100009.

[10] Parmesan, C., G. Anshari, P. Buotte, D. Campbell, E. Castellanos, A. Cowie, M.R. Ferre, P. Gonzalez, E.L. Gunn, R. Harris, J. Hicke, R. Bezner Kerr, R. Lasco, R. Lempert, B. Mackey, P. Martinetto, R. Matthews, T. McPhearson, M. Morecroft, A. Mukherji, G.-J. Nabuurs, H. Neufeldt, R. Pedace, J. Postigo, J. Price, J. Pulhin, J. Rogelj, D. Schmidt, D. Schoeman, P.K. Singh, P. Smith, N. Stevens, S.E. Strutz, R. Sukumar, G.H. Talukdar, M.C. Tirado, and C.H. Trisos, 2022: Cross-Chapter Box NATURAL | Nature-Based Solutions for Climate Change Mitigation and Adaptation. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 303–309.

[11] http://cmp-openstandards.org/

1.3. NBS in water retention and sediment management

An increase in heavy rainfall is expected due to climate change. However, longer dry periods between rain events may also occur (Figure 1). Measures that retain the water within the landscape can in this way also help both mitigate flooding and the effects of drought.

An important aspect of management is to keep water and sediment in the local environment rather than allowing it to reach watercourses or infrastructure. This can be achieved by implementing measures that allow rainwater to infiltrate into the soil and slow the flow of surface runoff.

In this context, it is also paramount to avoid things that increase runoff such as soil sealing, drainage through pipes or ditches and loss of landscape diversity.

NBS can be situated in several different places throughout a catchment area and can work together to keep water and sediment within the landscape during/after (extreme) rainfall events, by delaying the runoff of excess water and thereby protecting a large area beneath the measures. These measures are often smaller and easier to implement than structural solutions such as dams or retention ponds, which also capture water and sediment, but are often located further from the catchment area that has received heavy rainfall[12].

Examples of NBS in water and sediment management could be natural flood management measures such as afforestation, installing leaky dams or river and peatland restoration, which can contribute to a reduction in runoff and an improved flood protection effect.

Sediment has a natural role of keeping the bottom of the riverbed on the level where the groundwater table can serve the needs of the surrounding ecosystems. The typical problem of regulated rivers is the riverbed deepening (embedding) which automatically drains the groundwater, causing water shortages for every natural habitat and agricultural production.

Preventing further riverbed deepening can be achieved by re-naturalised river morphology, natural water retention and as part of it, natural sediment management.

In rural areas, actions to enhance water infiltration may include agricultural soil conservation measures e.g. keeping soil covered with crops or plant residues, reduced tillage or conversion to grassland. Buffer measures such as hedgerows, designated buffer strips along watercourses or at the end of fields and the implementation of grassed waterways in thalwegs or on known erosion-prone areas can also help mitigate the effect of intense surface runoff and potential soil erosion.

In urban settings, so-called green-blue infrastructure can help drain excess water away from streets and buildings and redirect rainwater from the (often overloaded) sewer systems. Examples include sustainable drainage systems (SuDS), green roofs, urban trees and green spaces (Figure 4).

[12] Seibert, S.P., Auerswald, K. (2020). Grundlagen der Abflussentstehung, Sturzfluten und dezentralen Hochwasserschutzmaßnahmen. In: Hochwasserminderung im ländlichen Raum. Springer Spektrum, Berlin, Heidelberg. https://doi.org/10.1007/978-3-662-61033-6_2

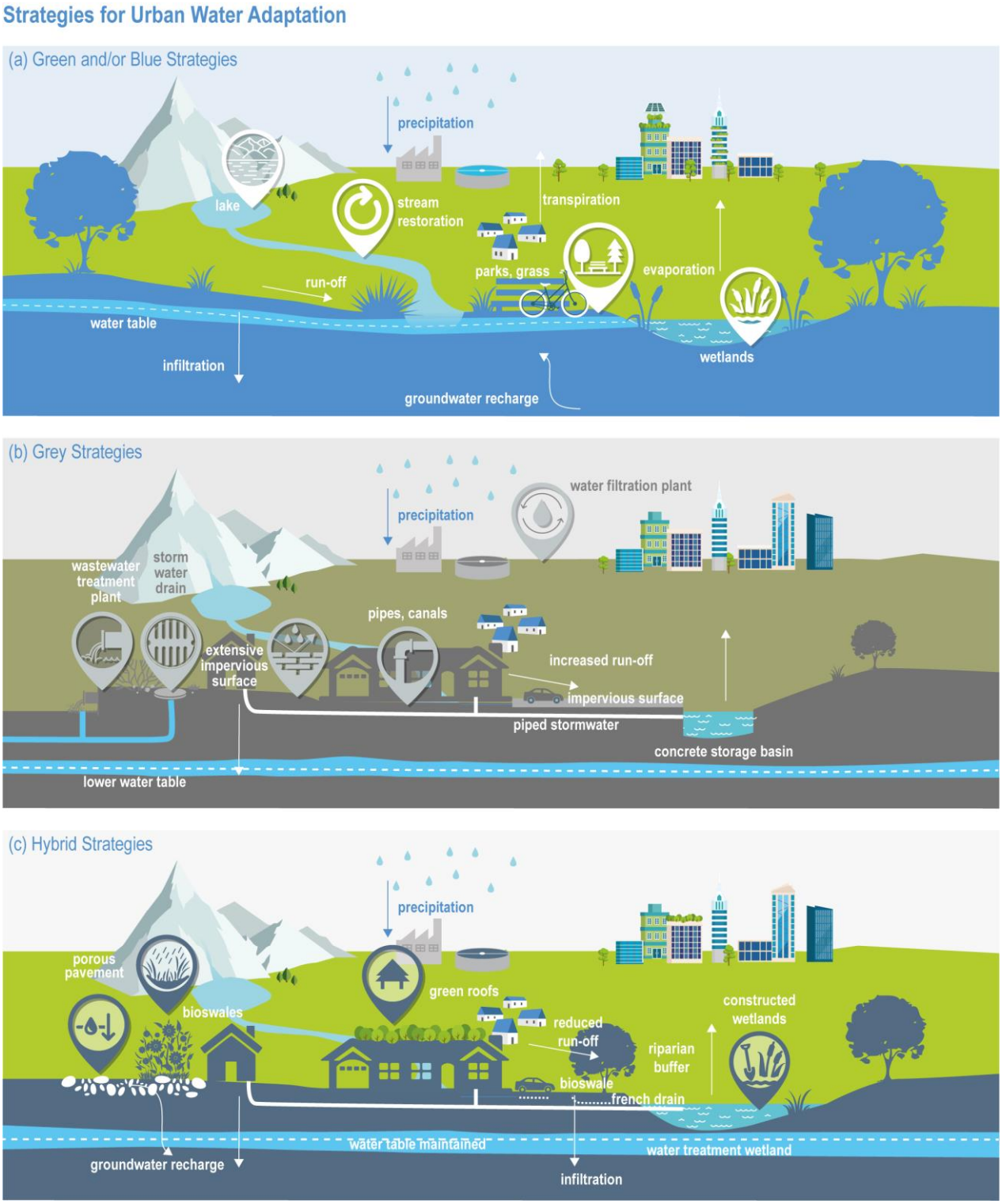


Figure 4: Diagrams showing different strategies for urban water adaptation including NBS in (a) green and/or blue strategies and (c) hybrid strategies compared to (b) grey strategies. [13]

[13] Figure 4.21 in Caretta, M.A., A. Mukherji, M. Arfanuzzaman, R.A. Betts, A. Gelfan, Y. Hirabayashi, T.K. Lissner, J. Liu, E. Lopez Gunn, R. Morgan, S. Mwanga, and S. Supratid, 2022: Water. In: *Climate Change 2022: Impacts, Adaptation, and Vulnerability.* Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 551-712, doi:10.1017/9781009325844.006.

1.4. Case studies of successful NBS projects worldwide

1.4.1. Habitat for City trees: Sponge City Concept

In order to give the roots of a tree sufficient space to spread in densely built-up urban areas, the Sponge City Principle is used. For this purpose, so-called Sponge City Substrate (coarse stable material, the spaces in between filled with fine organic material) is generously applied under the desired road structure, into which the tree roots can grow over time. Moreover, intentional infiltration of street water on site is given. The following Figure 5 shows a schematic sketch of a Sponge City:

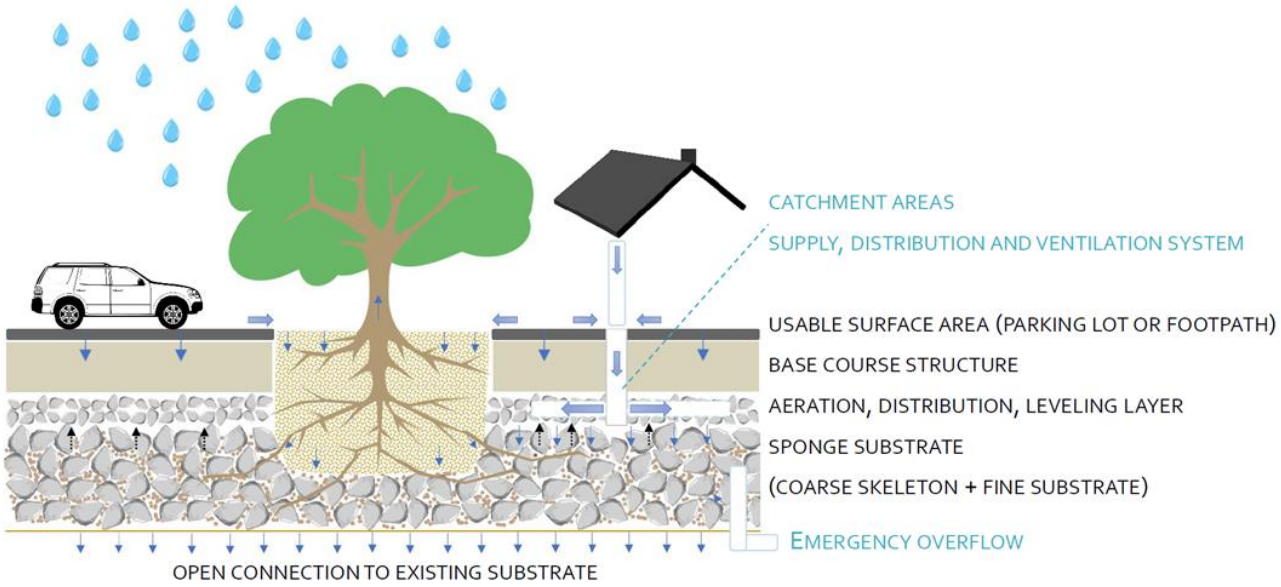


Figure 5: the Sponge City Principle, © BAW-IKT

The following example in Wolkersdorf in Lower Austria shows a picture of the construction of the Sponge City, the Sponge City Substrate extends under the whole parking area.

Figure 6: Sponge City concept under construction (left), the finished parking area in Wolkersdorf, Austria (right), Photo: © BAW-IKT

A further example for the Sponge City Concept can be found in Eggenberger Allee in Graz:

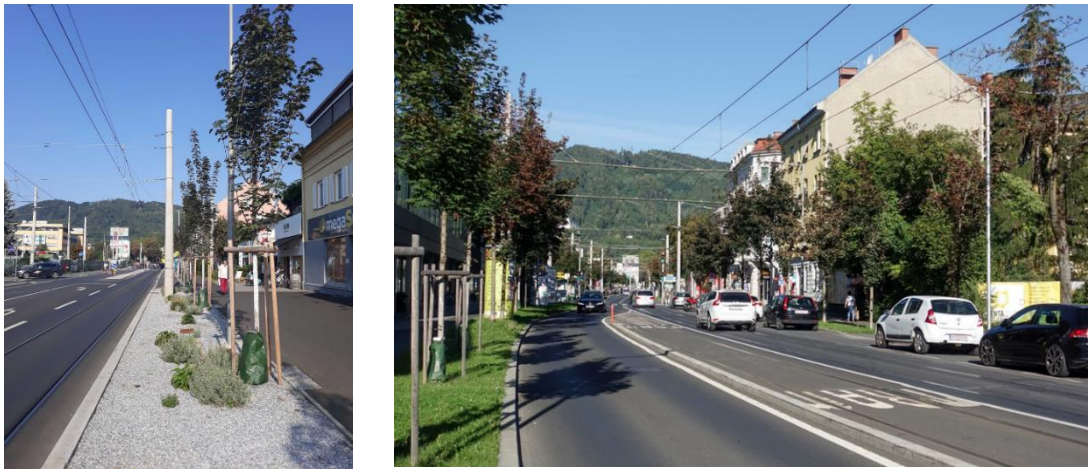


Figure 7: Sponge City concept in Graz, Austria[14]

1.4.2. Dual use of water retention areas: Rain Gardens and Infiltration Areas

An important aspect is to keep the water in the landscape. If such areas cannot be newly created, dual use is a possible solution. This can be implemented on a large or small scale.

Small projects can be found in more and more street swales and parking lots now, where excess rainwater is collected and slowly infiltrated into the ground. Green spaces in streets are usually elevated so that street pollutants do not harm the plants. For the intentional infiltration of street water on site, the rain gardens are planned at the lowest point of the cross-section and planted with resistant vegetation. Suitable planting provides cooling and biodiversity.

As an example, the Alte Poststraße/Kratkystraße in Graz, where the Sponge City Principle is also applied, is given here:

Figure 8: intentional infiltration of street water on site in Graz, Austria [15]

[14] online: Arbeitsgruppe Schwammstadt https://www.schwammstadt.at/projekte/eggenberger-allee-graz-freiland-zt , 14.03.2024

[15] right picture: https://link.springer.com/article/10.1007/s00506-022-00914-0 and left picture: https://www.meinbezirk.at/graz/c-lokales/reininghaus-wie-ein-kompletter-stadtteil-in-graz-ergruent_a4061292#gallery=null , 14.03.2024

Bigger scale solutions are retention basins in parks. As an example Parco Casarico in Sorengo (TI) in Switzerland is given. The publicly accessible park in a residential area is guaranteeing the management of surface water up to a 100-year storm event. The water is filtered and cleaned through phytoremediation in a central basin.

Figure 9: ecological continuity, on-site storm water management, and public accessibility across in a residential area in Sorengo, Switzerland[16]

1.4.3. NBS for Sediment management

Currently, only a few NBS have been implemented for sediment management in rivers and streams. Sediments should be retained in suitable places and transported further in unsuitable locations. One problem with NBS in connection with sediment management is probably the regular maintenance work, which will always destroy parts of the naturally occurring habitat in sediment basins. Nevertheless, at least parts can be designed nature-based.

[16] online: LILA - Landezine International Landscape Award https://landezine-award.com/casarico-park/ 14.03.2024

A good example for a NBS is a nature-based sand trap on the Curau near Horsdorf. The basin is planted with vegetation appropriate to the location. It must be dredged regularly for maintenance so that it does not lose its function.

Figure 10: a nature-based sand trap near Horsdorf, Germany[17]

Although a free-flowing river that transports sediment does not count officially as NBS, its sediment supply is essential for habitats worthy of protection such as coastal regions and deltas. In addition, the lack of sediment in rivers leads to riverbed deepening and subsequently to a drop in the groundwater level in the surrounding area. The river environment becomes drier and drinking water reserves may get limited. Therefore, the whole landscape needs good sediment balance in order to keep the ground water level.

By removing barriers in rivers and streams, the sediment can be mobilized again and follow its predetermined path towards the delta. Such dismantling operations are often only advertised as restoring passage for fish and other benthic creatures, but the further transport of sediments is just as important. The following examples can be shown as successful dismantling of such flow barriers:

During the renaturation of the Salantas River in Lithuania, a 94 meters wide and 4 meters high dam was dismantled. The picture shows the river before and after the renaturation.

Figure 11: before and after a demolition of a dam in Lithuania [18]

[17] online: Maßnahmenprogramm der FGE Schlei/Trave für den 2. Bewirtschaftungszeitraum https://wasserblick.bafg.de/servlet/is/157327/MNP_%20FGE_SchleiTrave_mit_Anlagen.pdf?command=downloadContent&filename=MNP_%20FGE_SchleiTrave_mit_Anlagen.pdf 14.03.2024

[18] online: Europäische Investitionsbank 2024 https://www.eib.org/de/stories/rivers-biodiversity-dam-removal-award 14.03.2024

Finally, in the following example on the Aa River, Pas-de-Calais in France, the changed sediment can be clearly seen when comparing before and after dismantling. The transport of sediment downstream is guaranteed again.

Figure 12: before and after a demolition of a barrier in France[19]

1.4.4. Flood prevention, flood-peak cut: Leaky Dams

The following link showing a video should serve as a last example. It shows a simple way to retain water in the landscape without much effort by Leaky Dams. Due to the length of the video, it can be seen as **additional input, but should not be shown in the training sessions.**

https://www.youtube.com/watch?v=bUBv8LJ6Wog&t=11s

Over 750 interventions have been implemented across the broader Frome Catchment area (Great Britain), which has resulted in a 1-meter reduction in peak river levels on the Slad Brook during heavy rainfall events, compared to similar occurrences in the past. [20]

For the actual trainings, it is recommended that case studies from the respective region/country are also presented. Participants could be encouraged to name and discuss natural or semi-natural places in their surroundings.

[19] online: Europäische Investitionsbank 2024 https://www.eib.org/de/stories/dam-removal-europe?recommendation=1 14.03.2024

[20] online: Stroud Distict Council https://www.stroud.gov.uk/environment/flooding-and-drainage/stroud-valleys-natural-flood-management-project/key-achievements-and-completed-project-case-studies 14.03.2024

1.5. Policies, regulations, permitting procedures and funding opportunities

Nature-based solutions can be perceived as an added value for projects dealing with climate change resilience by offering innovative, sustainable solutions and are often positively evaluated by authorities, which can be decisive in the permitting process[21].

Knowledge of relevant policies and regulations (at both EU, national and local level) are important throughout the planning and implementation stages of an NBS project to ensure a straightforward permitting procedure. Applying for relevant funding may also help increase the success of the project.

On the (local) municipal level, there are many policy documents where NBS could be integrated, such as documents defining spatial development, strategic development, environmental protection and long term financial forecast of a city[22].

Relevant EU Directives may encompass the Environmental Impact Assessment (EIA) Directive, the Strategic Environmental Assessment (SEA) Directive, the Habitats Directive, the Water Framework Directive (WFD) and the Floods Directive. The Common Agricultural Policy (CAP) may also be relevant as it requires farmers who receive subsidies to adhere to the standards on Good Agricultural and Environmental Conditions (GAEC) and includes possibilities for green infrastructure development.

The OPERANDUM project[23] mapped the legislation related to NBS at European level and found that NBS implementation is mainly regulated through the sectors of environmental protection and hazard management, land use and landscape planning, and building and construction. Although each country has its own legal system and regulatory approaches, case studies of NBS often go through a common path in the environmental protection sector, where the EIA/SEA Directives, the Habitats Directive and the WFD provide a common EU framework for national legislations to adhere to. The areas of land use, landscape planning and building are however, still governed by national regulations and also need to take into account local specificities.

By looking at certain elements of an NBS project it can be determined which regulation is applicable to ensure a smooth permitting procedure[24]:

- **Country, region specificity:** The type of governmental organization within a country mainly determines which authorities will be in charge of the different stages of the permitting procedure.
- **Stakeholders and scopes:** Whether an NBS is to be implemented as part of a private or public project or under plans and programmes from public authorities determines whether it needs to undergo an EIA or SEA.
- **Nature and size of the project:** The wide range of NBS means the type and size of the NBS project needs to be reflected in the permitting process.
- **Location:** A detailed description of the location should reveal the applicable legislation e.g. if the planned NBS will be located in an area of environmental protection.
- **Hazards**: Each specific hazard addressed by the NBS has its own legislation at both EU and national level, which must be consulted and applied.

[21] OPERANDUM, D2.1, OPEn-air laboRAtories for Nature baseD solUtions to Manage hydro-meteo risks: synthesis report of authorization/permission requirements at national level (2019).

[22] Somarakis, G., Stagakis, S., & Chrysoulakis, N. (Eds.). (2019) Thinknature Nature-Based Solutions Handbook. ThinkNature project funded by the EU Horizon 2020 research and innovation programme.

[23] OPERANDUM, D2.1, OPEn-air laboRAtories for Nature baseD solUtions to Manage hydro-meteo risks: synthesis report of authorization/permission requirements at national level (2019).

[24] OPERANDUM, D2.1, OPEn-air laboRAtories for Nature baseD solUtions to Manage hydro-meteo risks: synthesis report of authorization/permission requirements at national level (2019).

Several EU funding options exist and several research projects dealing with NBS have already concluded resulting in a great information pool on the topic, see e.g. https://research-and-innovation.ec.europa.eu/research-area/environment/nature-based-solutions_en. Examples of funding opportunities include the Horizon Europe Programme, the Programme for Environment and Climate Action (LIFE), the Regional Development Fund (ERDF), Interreg programmes, the Cohesion Fund, the Invest EU Programme, and the European Agriculture Fund for Rural Development among others (see below mentioned guide for more).

A guide to finding the right EU funding programme for the environment has been published by the European Commision. It contains examples of funding programmes and funded project, as well as a cross-reference table to identify appropriate funding programmes, whether you are seeking funding as a business, public authority, NGO or research institution[25].

Please insert relevant national/local policy, regulations, permitting procedures and funding opportunities here for the local mutations and trainings!

[25] European Commission, Directorate-General for Environment, *Find your EU funding programme for the environment – Supporting the environment under the 2021-2027 multiannual financial framework and NextGenerationEU*, Publications Office of the European Union, 2022, https://data.europa.eu/doi/10.2779/768079

2. Problems and associated NBS-interventions

2.1. Problems that can be solved by NBS interventions

As "users", we experience certain phenomena related to climate change: water on the road or in a field; mud on the road or a landslide; soil blown by the wind from the countryside onto roads or into a settlement. Whatever the cause, these phenomena cause problems that need to be solved. However, it is easier to understand if we know the cause. Therefore, the following grouping is used in this training material:

Table 1: Grouping used in this training material

Cause behind	WHAT WE EXPERIENCE "symptom", phenomena, "problem"	Theory / principle for solution
Floods (fluvial/pluvial)	Too much water on the roads and in the landscape	Water retention on site, as close as possible to where the rain falls: • Water Infiltration (give water the time to soak) • Water Retention (in a natural or artificial depressions) • Water Storage (in a natural or artificial reservoirs)
Sediment/Mud	Soil loss in the landscape, sediment loss in streams, mud on roads and in the landscape	Prevent mud washing out: • Erosion Prevention (keep land covered vegetation, slow-the-flow of water) • Sediment/Mud Retention (mud- or sediment-trap, slow-the-flow of water)
Drought	Lack of water in soil and air (moisture)	Prevent moisture loss: • Water Reuse • Keep Soil Moisture (keep land covered, slow the wind to keep the small water cycle working) • Increase Groundwater Level (by infiltration)

The 'small water cycle' is a helpful tool for understanding how water issues on land surface and moisture in the air work. It is crucial to have water in the landscape (settlement) to maintain moisture in the air and prevent dehydration of plants, people, and animals. The daily cycle involves evaporation during the day, which removes water into the air. In the evening, as the air cools down, moisture condenses as dew. This provides a water supply for plants, animals, and the soil, and also provides humidity for a healthy quality of life for people.

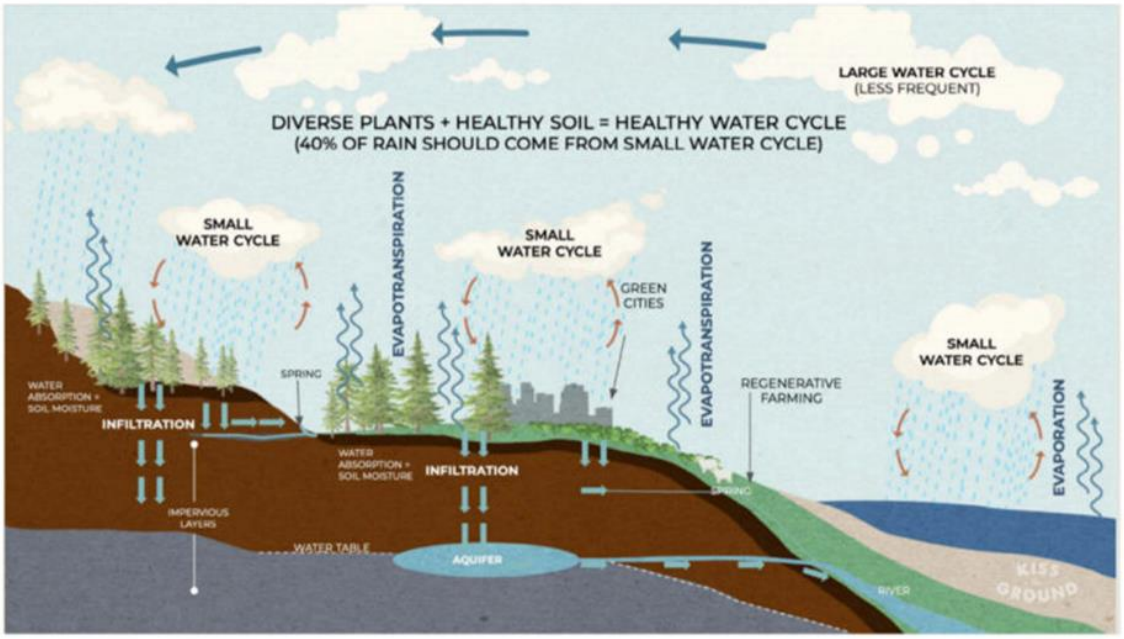


Figure 13: The relation of and the difference between small and large water cycle. The vegetation has a great role in the small water cycle[26].

NBS methods can effectively address and prevent many of the issues listed below:

Fluvial flood… To prevent the river from overflowing its banks, it is essential to reduce the amount of water reaching the riverbed. This can be achieved by retaining water upstream in the soil, within the riverbed itself, or in side-pocket reservoirs. The soil has the capacity to absorb a significant amount of water. Preventative interventions help to slow the flow of water in various ways. Each method keeps some water. This allows the soil to absorb, retain and later release it for vegetation. Some water evaporates, providing atmospheric moisture that benefits vegetation and wildlife, as well as being part of the natural water cycle. The remaining water flows down during and after storms or rainfall and can be managed smoothly within the riverbed.

Pluvial flood… During periods of heavy rainfall, water cannot flow away in a regular drainage system or be absorbed by the soil. This is often due to too much water arriving in a short period of time. To prevent this, better drainage systems, appropriate reservoirs with reasonable capacity, well-designed rain gardens, and infiltration parks are needed. It is also important to prevent inflow from surrounding areas.

During heavy rainfall or snow melting, water may accumulate on fields due to frozen or compacted soil, or soil that is already saturated. This can prevent water from being absorbed, even at deeper levels.

[26] online: https://greenwichfreepress.com/wp-content/uploads/2021/04/one-water-graphic-1170x785.jpg, 08.04.2024

Sediment movement, muddy flood and landslide… During heavy rainfall, water runs down uncovered land, washing away soil particles and causing soil to slip in some cases. This sediment-laden water can also reach rivers and lakes, leading to a deterioration in water quality.

Drought… Extreme dry weather can cause damage both in settlements and in the surrounding landscape. To balance this, replacement of the missing water or prevention of water loss is necessary. It is important to note that drought is not just the lack of rain; atmospheric drought can also occur, resulting in scorching of plant leaves or even death of branches or entire plants. This stress weakens the plant. It makes the plant more vulnerable to pests and fungi, reduces yield and allows weeds to take over. As a result, more chemicals are required to protect the crop.

2.2. The theory of NBSs leading to water retention and sediment management

Nature Based Solutions (NBS) utilise natural processes to achieve the goals. Often, this involves returning to traditional methods and allowing natural processes to take their course. For example, heavy rainfall can cause flooding and soil erosion. In settlements and landscapes, NBS methods differ, but they are interrelated.

It is important to consider the entire process, from the initial rainfall to the resulting water overflow on every square metre of land. The issue arises when water or mud (soil) moves away. To address this problem, it is important to keep water on site. This can be achieved by preventing down-flow, slowing the flow and retaining water. Retention helps to prevent the problem of parallel mud/soil movement.

In case of dry conditions and uncovered soil surface, deflation can cause a similar problem. Soil is lost on one site and deposited soil causes problems on streets, roads or land.

So, the message is: SLOW DOWN and RETAIN WATER.

The main principle is to store water in the soil, allowing time for the soil to soak.

Methods: To slow down the flow of water, natural structures can be used. Water can be retained in reservoirs, and sediment can be trapped in vegetation and sediment traps.

To achieve maximum effectiveness, use many small tools.

Water retention in the soil has a positive impact by acting as a reserve of water during dry periods when vegetation and crops experience water shortage. This helps to balance the periods with different precipitation characteristics.

The water balance is determined by the amount of precipitation and inflow versus evaporation and outflow. If there is a water shortage, it is important to retain the available water.

2.2.1. Floods (fluvial/pluvial)

2.2.1.1. Water Infiltration and Water Retention

The basis of flood prevention and mitigation is ensuring water is in the right place, such as in the landscape and soil. Downstream locations require special attention to the gathering and downflow of water, making **upstream actions** crucial.

☺ **Slow-the-flow** in the upstream catchment: **keep the water on sight** and give the soil time to soak

Keeping water on site for longer periods give the soil time to soak water, preventing downstream flow and providing storage for later use. This has a dual benefit: preventing floods (or reducing flood peaks) and storing soil moisture for dry periods. The following natural-based solutions (NBS) techniques are known to slow down the flow:

- Leaky dams: beaver-dam, coarse woody debris ponds
- Semi-natural reservoirs: infiltration/retention areas/basins
- Ponds and lakes, storm-ponds, earth bunds, Stroud
- Protection forests: restoring and protecting forests and wetlands in catchments, creating new protection forests
- Land conversion: afforestation / reforestation, preferably with semi-natural forest with 3-4 canopy levels and shrub zone and herbal zone

☺ **Giving more space for the river, for the water: re-activating former floodplain areas (especially on lowland areas)**

During the high-water season, the former floodplain area of rivers stored a significant amount of water. The soil absorbed some of the excess water, while the rest remained in the area and drained down later. These high polders or former floodplain areas are now separated from the river by flood protection dykes, which puts additional pressure on the riverbed. To store water with nature-based solutions (NBS), it is advisable to reactivate former floodplain areas that are not built on or affected by infrastructure. Always remember that a natural depression will never pose a threat of flood damage. Several small interventions can have a considerable impact when used together. Productive utilisation of periodically inundated areas is possible with the application of adaptive land use forms.

The following techniques result in more natural rivers and floodplains:

- Re-connected floodplain: create new flooded zones, “side-pockets” (bays) for water storage, fish rest and spawning

☺ **Stream/river bed re-naturalisation**

Natural riverbeds can store more water due to their longer, curved shape and natural operation. The sediment amount and micro-relief in the riverbed provide water retention and increase the elevation of the groundwater level in the surrounding area. Vegetation also contributes to retention and healthy air moisture content through evaporation:

- Stream/river bed re-naturalisation: re-curving river beds and canals, slight slope, broken coastline, natural sediment movement and micro-relief in the river/streambed
- Stream Daylighting: culvert removal

- Living Embankment: zoned vegetation along the banks and further, in relation with water depth and durability

☺ Changes all along the river-course/in the catchment

Changes along a river or watercourse can have an additive impact. Therefore, it is worthwhile to apply various methods, both on the river and its floodplain. Changes in morphology and water inundation, as well as soil moisture content, require changes in land use. With careful planning and support from state (EU) payments, financial benefits can be generated beyond ecosystem services. This has a key importance in getting back the healthy operation of the landscape, due protected and safe environment for people.

- Land conversion: arable -> grassland -> forest, afforestation / reforestation, preferably with semi-natural forest with 3-4 canopy levels and shrub zone and herbal zone, agroforestry
- (constructed) Wetlands and floodplains
- Protective forests and wetlands
- Agricultural management changes (on arable fields to prevent down flow): traditional land use re-introduction, reduced/no-tillage, mulching, continuous soil coverage, greening (=green winter), contour-farming, cover cropping, perennial crops, crop diversification,
- Landscape structure and buffering measures: terracing, agricultural parcel size and arrangement change, tree and bush stripes

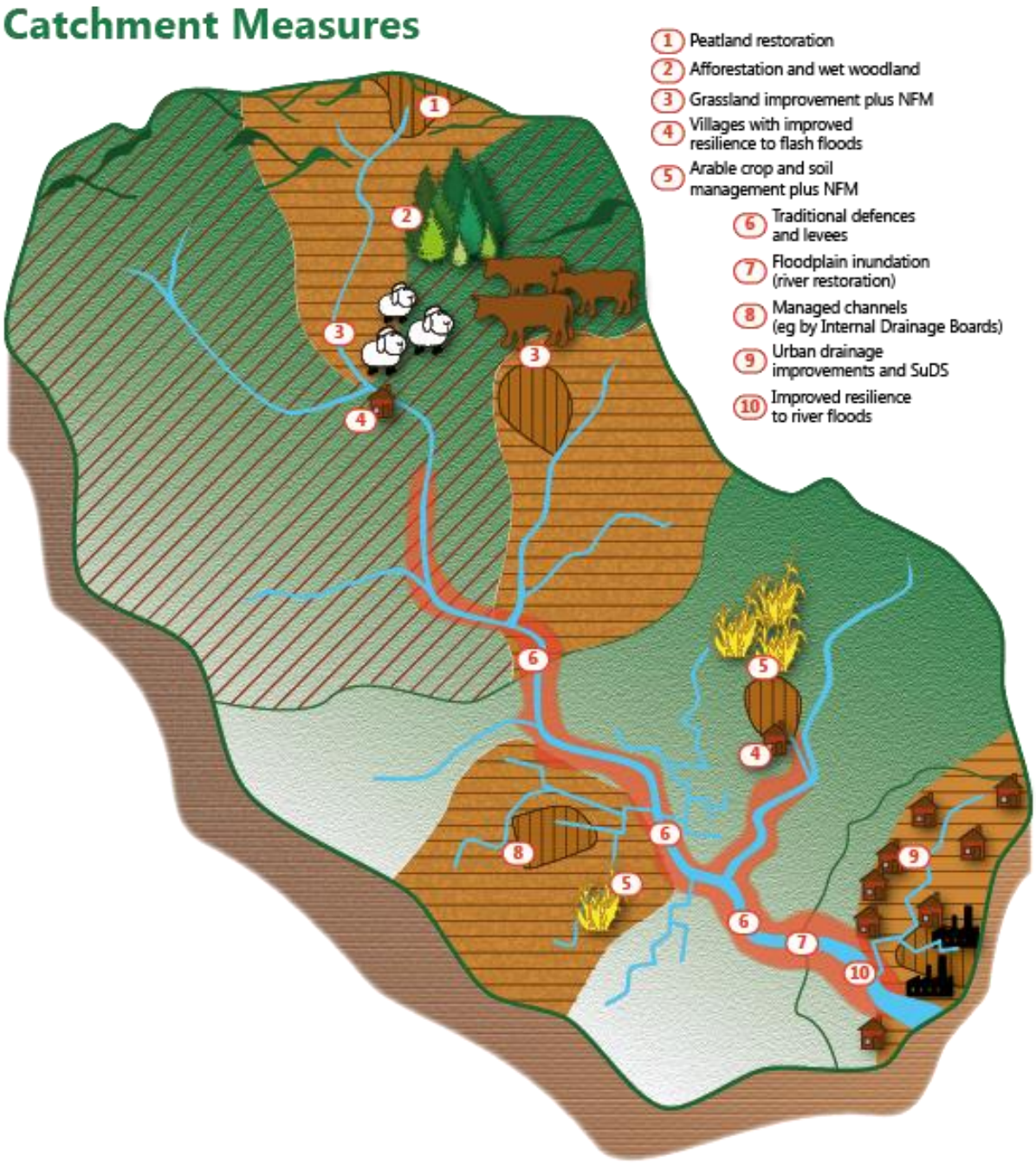


Figure 14: Geographical distribution of flood prevention measures[27]

[27] online: https://publications.parliament.uk/pa/cm201617/cmselect/cmenvfru/115/11505.htm, 08.04.2024

2.2.1.2. Water Storage

Flood prevention and mitigation rely on retaining water. Ideally, rainwater should remain where it falls. Rivers and waterways can transport excess water to areas in need. However, human intervention is often necessary due to changes in natural logistics. Various methods exist for water storage, all based on the same principles:

- Stops certain parts of the water that would run down
- By storage, water stays for longer on a site -> flood peak is cut down (slow-the-flow)
- Longer stay gives the soil more time to soak up the water
- Soaked soil stores water for the dry period until the next rain or high water period
- Water reservoirs communicate with each other in the soil and provide their surrounding with water (soil moisture)
- The water storage capacity of an area depends not only on its soil structure and depth but also on its vegetation

One practical application of these principles is rainwater harvesting, a process that involves collecting and storing rainwater from roofs and other hard surfaces for later use. If designed appropriately, these systems can offer multiple benefits in urban areas such as reducing the costs of water infrastructure, decreasing household expenditure on water and lowering stormwater management costs. In contrast to Water Retention systems mentioned in the previous chapter, which tend to be used in non-urban areas due to their space requirements, Water Storage tend to be used in cities and densely built-up areas.

☺ NBS methods that serve to store water in urban areas

- Rain gardens: open grassed ditches along roads/swale-trench system
- Retention and detention basin: storm reservoir in the town
- Bioswale
- Constructed wetland
- Green roofs: rooftop gardens
- Rainwater harvesting: rainwater storage/cistern

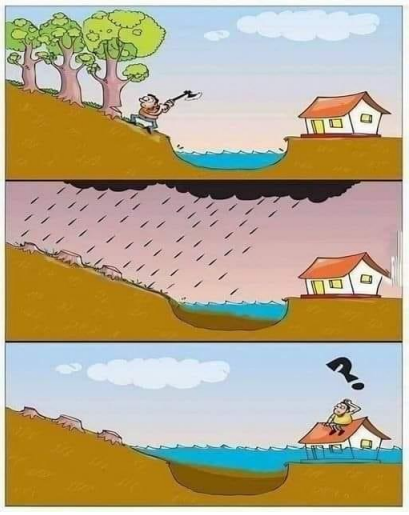


Figure 15: The role of vegetation in flood prevention

2.2.2. Sediment/Mud

2.2.2.1. Erosion Prevention and Sediment/Mud Retention

Heavy rainfall causes soil erosion and loss, as well as deterioration of water quality when sediment-laden water reaches rivers and lakes. In severe cases, saturated soil masses can slide down from certain areas. Strong winds can also cause soil loss and deflation.

NBS, such as vegetation cover or terracing, can help prevent soil erosion by reducing the impact of rainfall and wind on soil surfaces. Vegetation roots bind soil particles together, while the aboveground vegetation acts as a physical barrier, slowing down the flow of water and reducing its erosive force. Additionally, vegetation serves as a natural buffer that traps sediment, preventing it from entering rivers and preserving water quality. Agricultural management changes can also improve soil health and stability.

To prevent sediment/mud from washing out, follow these principles:

- Erosion prevention
  - Keep local precipitation on site
  - Enhance stability of soil
  - If water flows down: slow-the-flow
- Sediment/Mud Retention and Trapping
  - If water flows down: slow-the-flow
  - If water still flows down: trap the sediment laden water

Some of the following techniques are also mentioned in the chapters describing Water Retention because NBS can serve more than just one benefit.

☺ Slow-the-flow in the upstream catchment: keep the water on site and let the soil to soak (give time)

Keeping water on site for longer periods allows the soil to absorb more water, preventing downstream flow and providing storage for later use. This technique has a double advantage: it prevents floods (or reduces flood peaks) and stores soil moisture for dry periods. To slow the flow, use the following techniques:

- Agricultural management changes: micro-dams between ridges
- Landscape structure and buffering measures: buffer strips

☺ Continuous soil coverage for erosion and soil loss prevention on the upper catchment area

NBS can provide forest rehabilitation services to increase forest cover or convert an existing forest into a healthy one. Examples include:

- Land Conversion: natural forest rehabilitation, afforestation / reforestation, preferably with semi-natural forest with 3-4 canopy levels and shrub zone and herbal zone
- Protective forests and wetlands

☺ Continuous soil coverage for erosion and soil loss prevention through agricultural management changes

Implementing sustainable agricultural practices can improve soil water-holding capacity, prevent erosion and reduce soil loss. These practices can also enhance soil regeneration, including increased water and moisture storage capacity, higher nutrient content and improved soil life.

Re-introducing traditional land use can also help mitigate these issues. Crop rotation and cover crops can help maintain soil health and structure. Different crops have varying root systems and nutrient needs, which can prevent soil erosion by holding the soil in place and reducing runoff.

Minimizing tillage or adopting conservation tillage practices can also preserve soil structure and reduce erosion. Tilling disrupts the soil, making it more susceptible to erosion by wind and water.

Planting crops along the contour of the land can also help to slow down the flow of water, reducing erosion. This method uses the natural slope of the land to minimise runoff and soil loss.

Examples:

- Agricultural management changes: reduced/no-tillage, mulching, continuous soil coverage, greening (=green winter), contour-farming, cover cropping, perennial crops, crop diversification,
- Landscape structure and buffering measures: terracing, agricultural parcel size and arrangement change, tree and bush stripes, grassed waterways
- Land conversion: agroforestry

☺ Sediment trapping

Sediment trapping refers to the ability of natural ecosystems or engineered structures to capture and retain sediment, preventing it from being carried away by water runoff. Constructed wetlands or retention basins act as sediment traps by slowing down water flow and allowing suspended sediments to settle. This method is a form of mitigation and does not prevent soil loss and erosion. Unlike the other theories mentioned, sediment trapping only captures sediment and does not address the root cause of soil loss and erosion.

Examples:

- Landscape structure and buffering measures: local sediment retention basin near erosion hot spots
- Constructed wetland

☺ Deflation prevention

Strong wind causes soil deposits and losses (deflation). Windbreaks or shelterbelts are important for reducing erosion. They act as barriers that slow down and disrupt the flow of wind across open landscapes. Slower wind speeds reduce the erosive force of wind on soil particles, preventing them from being lifted and carried away.

The vegetation in these belts creates a microclimate that promotes better soil moisture retention and reduces water stress on plants. This further contributes to erosion control. Additionally, wind strips can serve as habitats for various plant and animal species, enhancing biodiversity.

Examples:

- Landscape structure and buffering measures: shelterbelts/windbreaks/hedgerows/field margins
- Agricultural management changes: vegetative cover, contour farming

2.2.3. Drought

Our training focuses on nature-based solutions to mitigate the impacts of excess water or sediment. Many of these solutions also play a significant role in mitigating drought. Therefore, this chapter covers some of the phenomena and methods related to drought.

Symptoms of drought and atmospheric drought, such as low rainfall, dry soil, heat waves, hot air, lack of dew, and scorched tree leaves, are noticeable in both urban and natural areas.

To manage the negative impacts of drought, the main aim is to:

- Reduce and prevent water loss
- Replace missing water
- Increase water supply

2.2.3.1. Water Reuse

The amount of water that is available can be increased and/or used more wisely than it is done now. For example by gaining water from rainfall: roof water or rainwater from other hard surfaces can be used for irrigation or the toilet flush. Greywater can be recycled in a household and also on a larger scale.

Examples:

- Bioswale
- Constructed wetland
- Green roofs: rooftop gardens
- Rainwater harvesting: rainwater storage/cistern

2.2.3.2. Keeping the Soil Moist

Water retention: improves the microclimate, restores the small water cycle

Appropriate moisture content in the air and in the soil is important for the plants to grow well, humidity contributes to the health and well-being of humans and wildlife. Soil and air humidity improves the microclimate and restores the small water cycle.

Wetlands keep the moisture on site and vegetation prevents the wind from carrying away the moisture. Restoring and protecting forests and wetlands in catchments is, among other things, a good solution for keeping moisture in the soil.

Examples:

- Protective forests and wetlands
- Re-connected floodplains
- Land conversion: afforestation/reforestation
- Agricultural management changes: vegetative cover
- Parks / green corridors

Changing farming technologies and crop species and varieties

Farming is responsible for several negative impacts, while suffering due to the same negative impacts, created by itself. To implement changes in farming is unavoidable, especially because the productivity of agriculture declines while overusing natural resources.

So, to avoid the evaporation of water from the soil, change for example the vegetation to drought resilience vegetation, or do a second-crop or do mulching.

Examples:

- Land conversion: agroforestry
- Agricultural management changes: vegetative cover, reduced/no-tillage, mulching, greening (=green winter), contour-farming, cover cropping, perennial crops, crop diversification,

Increased shading and soil cover

Covered soil is richer in moisture, provides good soil structure, supports natural procedures and rich microorganism processes. Coverage can be alive vegetation or (on cultivated sites) dead organic matter either from previous crop or mulch layered on purpose.

Shaded soil can support microorganisms to provide good soil fertility. Natural vegetation nearly always covers the soil surface, and in highly fertile areas always. Tree and bush stripes can be easily planted to increase shading.

So, also keep oasis in towns and not just on a field, the vegetation in towns and cities provide natural shade, moisture balance and nice feeling as well. Microclimate with proper moisture content is essential for people and all living creatures.

Examples:

- Land conversion: agroforestry, afforestation/reforestation
- Agricultural management changes: vegetative cover, mulching, greening (=green winter), cover cropping

2.2.3.3. Rising the Groundwater Level

A healthy groundwater table can also help to prevent a period of drought by providing the plants with moisture from the subsoil during periods of low rainfall. The vegetation, which does not suffer from drought stress due to the sufficiently high groundwater table, remains healthy and continues to provide shade and cooling for the surrounding area.

In times of sufficient rainfall, infiltration into the subsoil can be supported, either by keeping the water in place long enough for it to seep, or also by artificially filling the groundwater reservoir by diverting watercourses.

Examples:

- Permeable Paving System
- Infiltration basin
- Bioswale
- Parks / green corridors
- Re-connected floodplains

2.2.4. Extra Services provided by NBS

In our textbook, we concentrate on nature-based solutions for mitigating the impacts of excess water or sediment. However, NBS typically serve multiple purposes, as they are inherently intertwined with nature. The effects of a NBS are as varied as nature itself. Below, we outline and describe some of the numerous benefits of these NBS.

2.2.4.1. Cooling

NBS can help communities adapt to climate change impacts such as heatwaves and droughts by providing cooling effects and regulating the water availability.

Urban areas often experience the "heat island effect," where temperatures are significantly higher than surrounding rural areas due to the concentration of buildings and pavement. NBS such as urban forests, green roofs and green spaces help mitigate this effect by providing shade and evaporative cooling, reducing the need for energy-intensive air conditioning and lowering emissions from energy production.

2.2.4.2. Air Quality and Noise Reduction

Nature-based solutions (NBS) contribute to the mitigation of air quality and noise reduction through several mechanisms. Trees, plants and other green infrastructure act as natural filters for air pollutants. Through a process called phytoremediation, plants can absorb pollutants such as carbon dioxide, nitrogen oxides, sulphur dioxide and particulate matter, thereby improving air quality.

Trees and plants release oxygen as a by-product of photosynthesis. Increasing vegetation through NBS can lead to higher oxygen levels in urban and suburban areas.

Vegetation can act also as a natural barrier to absorb and reduce noise pollution from sources such as traffic, industrial activities and construction. Trees and shrubs in urban areas help buffer sound waves, dampening noise levels and creating quieter, more pleasant environments for residents.

2.2.4.3. Biodiversity

NBS can provide habitats for diverse plant and animal species, supporting ecosystem health and biodiversity. This can enhance resilience to environmental changes and promote ecological balance.

NBS projects often involve restoring degraded ecosystems or creating new habitats. This includes projects such as reforestation, wetland restoration and establishing green corridors. By providing suitable habitats, NBS support a variety of plant and animal species. Through NBS projects, green corridors can be established to promote ecosystem connectivity. This allows species to move more freely between habitats, facilitating gene flow and increasing resilience to environmental changes.

Very often NBS involve planting a diverse range of native plant species. Native plants are well adapted to local environmental conditions and support a variety of native wildlife, including insects, birds and small mammals. Furthermore, healthy soils are essential for biodiversity, as they support a diverse array of microorganisms, fungi and invertebrates. NBS projects that focus on soil conservation and restoration help maintain soil fertility and biodiversity.

2.2.4.4. Beauty / Appearance

Green spaces, parks and trees that are created through NBS do not only provide beautiful landscapes but also recreational opportunities for communities, promoting physical and mental well-being.

Further benefits can be the improvement of water quality by filtering out pollutants or carbon sequestration by capturing and storing atmospheric carbon dioxide. Investing in NBS can also yield economic benefits such as reduced infrastructure costs and foster the social cohesion in communities.

2.3. The difference in NBS theories in a settlement and in the landscape

The impact of weather can cause similar phenomena both inside and outside of a settlement. However, the impact on human lives and values can be vastly different. Therefore, techniques for prevention, management and mitigation should focus on human lives and values within a settlement.

Settlements are often located in valleys, along rivers or creeks. A danger associated with these locations is the potential for extreme amounts of water due to heavy rainfall, to overwhelm the settlement's drainage system and cause **pluvial flooding**.

In a downstream section of a river, the water from the upper catchment can accumulate and cause **fluvial flooding**.

This can result in streets and homes being submerged, and may also cause **muddy floods or landslides**. **Sediment and mud** can be displaced to the wrong places.

Both prevention and management (mitigation) are important for settlements, while in landscapes, it is a matter of deciding whether inundation causes problems or not. To prevent flooding, similar interventions to those used in settlements can be employed. Mitigation techniques include changing land use from arable to grassland or forest, altering planting and crop schedules to account for spring floods and excess water, and implementing retention and slow drainage systems to divert water to rivers or creeks.

Prevention and management techniques are also similar in both cases, targeting the upstream sections of water flows and the outer regions of settlements and landscapes.

Outside of settlements, similar phenomena occur, but the management methods differ.

Both **fluvial and pluvial floods** have a similar impact on the landscape: lands become inundated. In historic times, some of these areas were temporarily or continuously covered by water. Therefore, it is advisable to use water-tolerant land use forms in these areas.

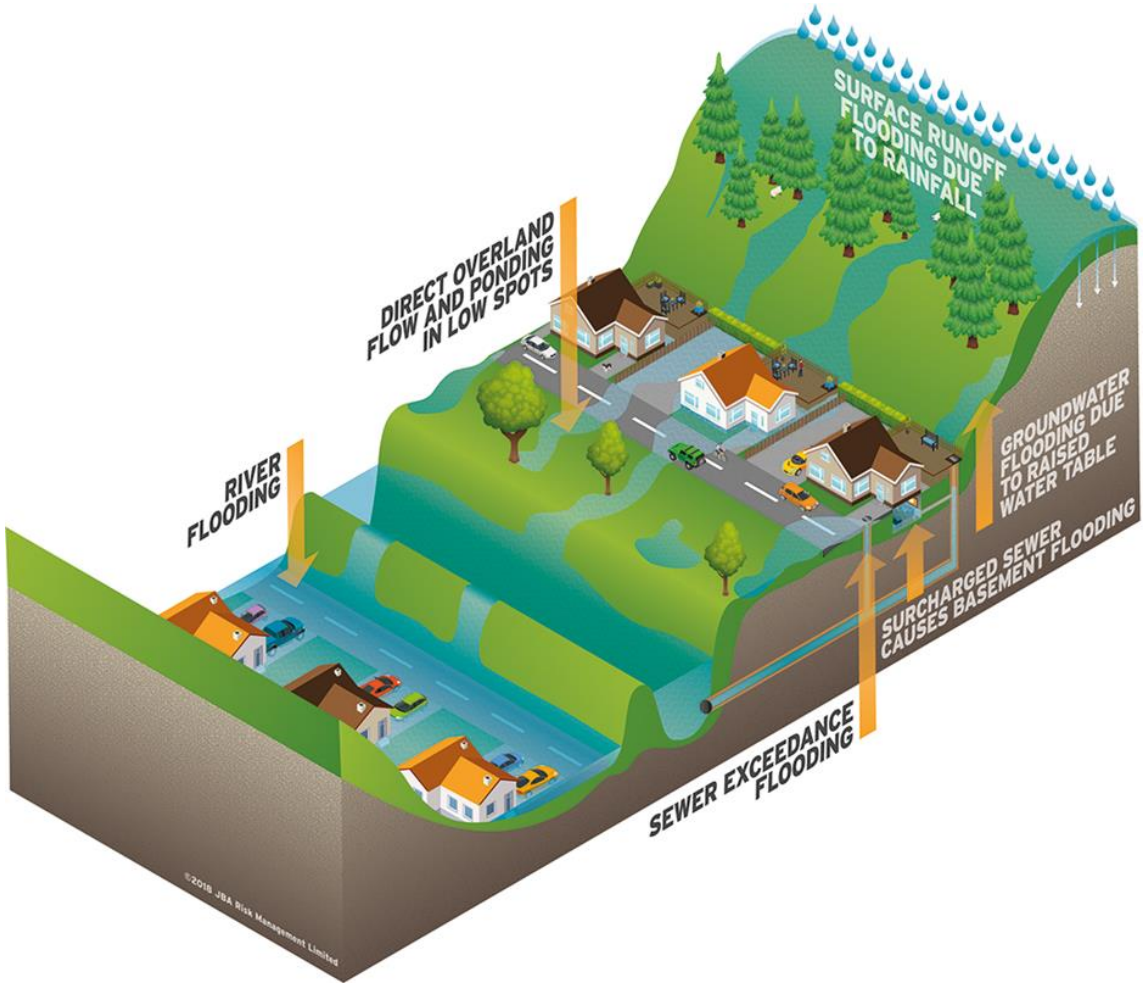


Figure 16: Main sources of inland flooding, including river and surface water flood[28]

2.4. Multiplication and magnification of certain NBS methods

NBS methods can be implemented on a small scale with little effort. Implementing larger-scale solutions may require more space, costs, and persuasion among the population. However, larger-scale solutions have a greater ecological impact.

Although small-scale methods are generally cheaper, many of them need to be applied to achieve a large impact. Implementing small-scale NBS may seem like a disadvantage, but once in place, they provide good examples for future projects and help to convince people.

One small NBS has already made an ecological start. Additionally, in many cases, the impact is greater than the sum of individual effects. Many small projects staggered over time may exceed the effect of one large project.

To get a feel for it, begin with a small-scale approach. Small, easy-to-implement NBS measures offer benefits to a local community:

- Small, little area requirement

[28] online: https://www.jbarisk.com/news-blogs/an-introduction-to-flooding-terms/

- Usually cheap (with exceptions)
- Easy, time saving, local effort to construct (with exceptions)
- Sometimes, just very simple engineering design is needed only
- One engineering design can be copied on many sites (with slight adaptation)
- Simple rules for permissions (may vary from country to country)
- Many of them can be combined with each other
- Aesthetically pleasing
- Has additional advantage: good soil structure (due to soil coverage), fertile lands (due to prevention of topsoil loss), productive agriculture (due to healthy groundwater table), nice parks and lakes in a settlement, etc.

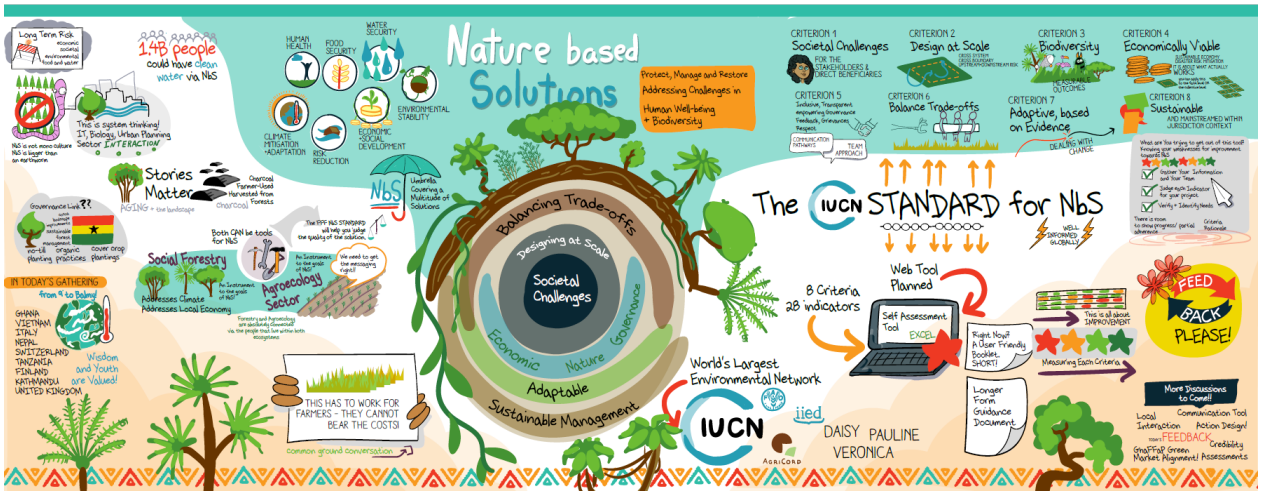


Figure 17: Global Standard for Nature-based Solutions[29]

29 https://www.iucn.org/news/nature-based-solutions/202105/farmer-organisations-and-global-standard-nature-based-solutions-illustration

2.5. Types of Nature-based Solutions

2.5.1. Permeable Paving System

Description

Permeable paving systems are surfaces that are able to absorb storm water, thereby minimising and delaying surface water run-off, while reducing the amount of pollutants. After storm events, the water trickles either through the permeable surface itself, or through gaps or funnels between pavers. Water is then temporarily stored in the underlying stone layer and infiltrates into the soil or to an additional drainage layer that conveys water into the sewage system (subsurface drain). They are commonly installed in parking lots, residential streets or sidewalks. There are many different systems of permeable pavements. For example, porous asphalt and permeable concrete improve infiltration of homogeneous surfaces. Other solutions such as vegetated grid pavers increase the share of substrate or vegetation cover for better infiltration and allow for water uptake by plants. Solutions such as permeable stone carpets provide macropores for gravity-driven percolation[30].

Boundary conditions - Limitations

- Implementation on new or existing building sites
- Prior analysis of the soil is necessary
- Compatibility with all kinds of street usage should be considered
- Limited load on paved area - often not applicable for high speed or highly trafficked roads
- Prone to clogging without regular maintenance

Similar Terminology/Systems

- Draining pavements
- Pervious pavements
- Openwork plate
- Vegetated grid pave
- Permeable concrete
- Porous asphalt
- Permeable stone carpet
- Surface unsealing

More information:

- UNaLab: Nature-based Solutions Technical Handbook Factsheets
- susdrain - sustainable drainage systems (SuDS)

[30] UNaLab, Nature-based Solutions Technical Handbook Factsheets, https://unalab.eu/en/documents/unalab-nbs-technical-handbook-factsheets

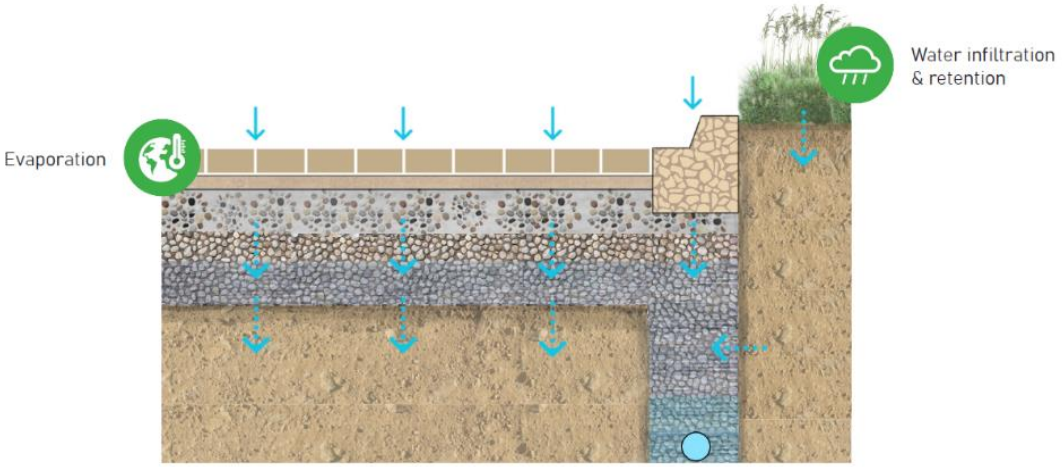


Figure 18: Example of a permeable paving system, ©UNaLab[31]

Figure 19: Permeable paving system in Stuttgart, Germany[32]

[31] handbook of UNaLab URBAN NATURE LABS, Institut für Landschaftsplanung und Ökologie, page 121

[32] UNaLab, Nature-based Solutions Technical Handbook Factsheets, https://unalab.eu/en/documents/unalab-nbs-technical-handbook-factsheets , page 120

Figure 20: Permeable stone carpet (www.drenatech.com)

Table 2: Benefits of a Permeable Paving System:

Floods (fluvial/pluvial)	Water Infiltration	+
	Water Retention	+
	Water Storage	
Sediment/Mud	Erosion Prevention	
	Sediment/Mud Retention	
Drought	Water Reuse	
	Keep Soil Moisture	
	Increase Groundwater Level	+
Extra Services	Cooling	+
	Air Quality and Noise Reduction	
	Biodiversity	
	Beauty / Appearance	

2.5.2. Sponge City Concept

Description

To give the roots of a tree sufficient space to spread, coarse stable material is installed and compacted, which transfers the loads of the street into the subsoil. A fine substrate of mineral and organic components is slurred into the large cavities of the coarse material. The rootable pore system allows air and water to penetrate the soil through its coarse pores. The roots of urban trees are reliably supplied with air, water and nutrients in the long term. They can spread under the solid surface and traffic areas without affecting them.

There is an open connection between the sponge city substrate and the subsoil. The water, that infiltrates into the system, can also infiltrate into the subsoil if necessary and the vegetation can access this water reservoir if required.

The sponge city concept is often referred to as the Stockholm system.

Boundary conditions - Limitations

- Sufficient space on surface and in subsoil required

Similar Terminology/Systems

- Low Impact Development (LID)
- Sustainable Urban Drainage Systems (SUDS)

More information:

- https://www.schwammstadt.at/
- https://www.sonnenerde.at/en/biochar/sponge-city

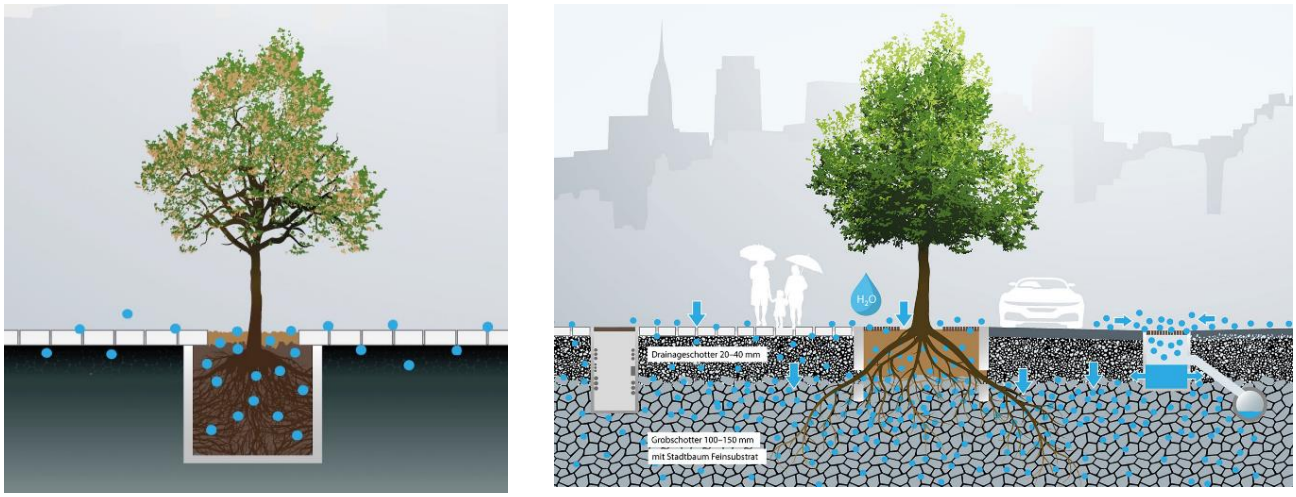


Figure 21: Left: current situation of many urban trees that were planted in the past; Right: Sponge City Concept[33]

[33] online: Sonnenerde GmbH https://www.sonnenerde.at/en/biochar/sponge-city 27.03.2024

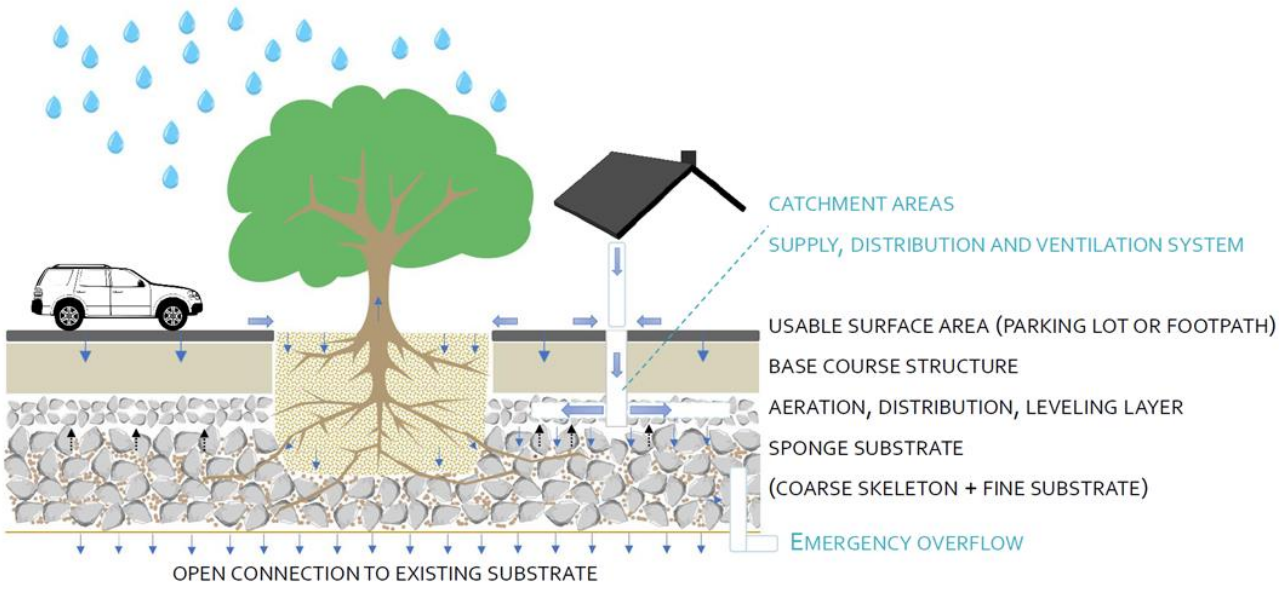


Figure 22: The Sponge City Principle, © BAW-IKT

Figure 23: Sponge City Principle in Alte Poststraße/Kratkystraße in Graz, Austria[34]

[34] online: right picture: https://link.springer.com/article/10.1007/s00506-022-00914-0 and left picture: https://www.meinbezirk.at/graz/c-lokales/reininghaus-wie-ein-kompletter-stadtteil-in-graz-ergruent_a4061292#gallery=null, 14.03.2024

Table 3: Benefits of the Sponge City Concept:

Floods (fluvial/pluvial)	Water Infiltration	+
	Water Retention	+
	Water Storage	
Sediment/Mud	Erosion Prevention	
	Sediment/Mud Retention	
Drought	Water Reuse	
	Keep Soil Moisture	
	Increase Groundwater Level	+
Extra Services	Cooling	+
	Air Quality and Noise Reduction	+
	Biodiversity	+
	Beauty / Appearance	+

2.5.3. Street Trees

Description

Urban trees in streets are visual and ecological advantages for urban life. They store carbon dioxide (CO2), filter dust and pollutants, provide shade and reduce the ambient temperature. They are often combined with low landscape elements, which also contribute to biodiversity.

The challenge of keeping a street tree healthy and long-lived is the availability of sufficient large planting pits and rootable space in the subsoil, as well as water. See therefore: Sponge City Principle.

Subsequent planting of Street Trees often leads to conflicts with existing installations. Therefore, a good overall conceptual planning is necessarily required.

Nevertheless, the effort is worth it: urban trees along small or large streets, in parks or on squares help cities to become climate-friendly and remain liveable.

Boundary conditions - Limitations

- Despite suitable technical concepts (sponge city concept), a tree needs a lot of space on the surface and in the subsoil. Sadly, a lack of space is currently often still in favour of traffic and against green spaces.
- Depending on site conditions and available space, appropriate tree species must be selected.
- The use of structural soils and permeable pavements may help improve growing conditions for urban street trees
- Allergic potential of pollen.

Similar Terminology/Systems

- Boulevards
- Single line street trees
- Tree groups
- Sustainable urban groves

More information:

- UNaLab: Nature-based Solutions Technical Handbook Factsheets

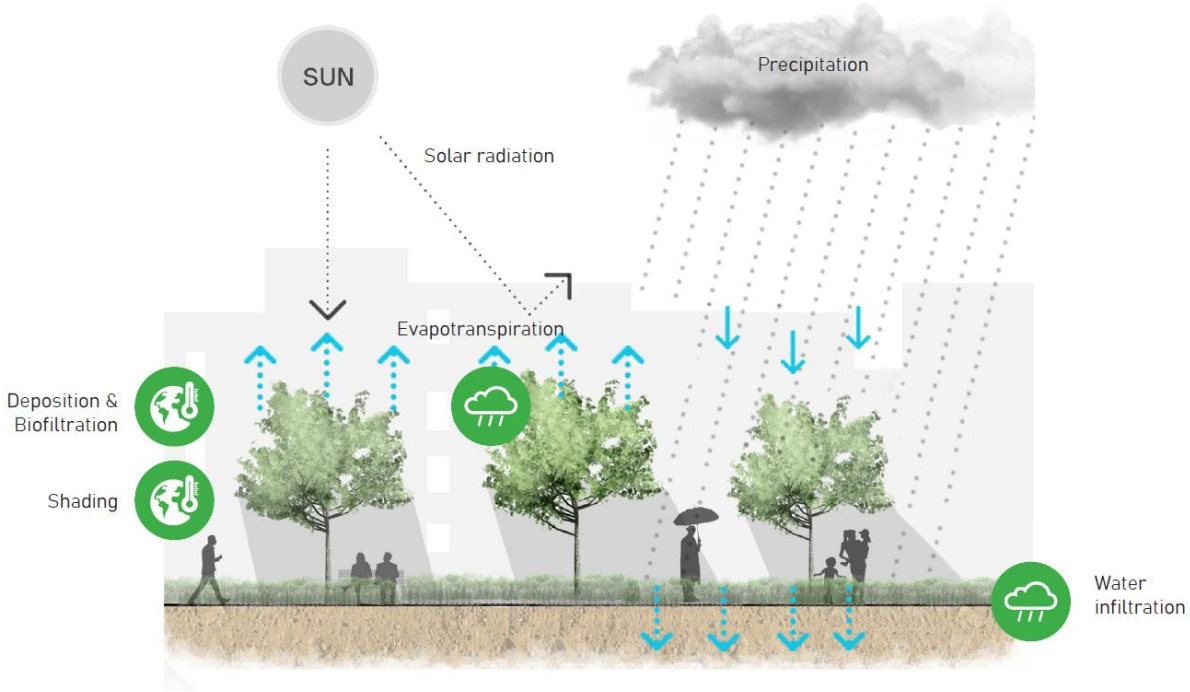


Figure 24: Street Trees and their associated natural processes and benefits, ©UNaLab[35]

Figure 25: Visualisation of a planned cycle highway in Vienna[36]

[35] handbook of UNaLab URBAN NATURE LABS, Institut für Landschaftsplanung und Ökologie, page 27

[36] https://www.fahrradwien.at/2022/02/04/praterstrasse-neu-radhigway-von-der-city-in-die-donaustadt/

Figure 26: Left: © BAW-IWB, Right: urban trees in Graz, using also the sponge city concept[37]

Table 4: Benefits of Street Trees:

Floods (fluvial/pluvial)	Water Infiltration	+
	Water Retention	+
	Water Storage	
Sediment/Mud	Erosion Prevention	
	Sediment/Mud Retention	
Drought	Water Reuse	
	Keep Soil Moisture	
	Increase Groundwater Level	+
Extra Services	Cooling	+
	Air Quality and Noise Reduction	+
	Biodiversity	+
	Beauty / Appearance	+

[37] https://www.naturpark-suedsteiermark.at/wp-content/uploads

2.5.4. Green Roofs

Description

Green roofs, a key component of urban green infrastructure, come in three main types: extensive, intensive and constructed wet roofs. Extensive green roofs are lightweight, low-maintenance systems with shallow-rooted vegetation, offering benefits like localised temperature and pollution reduction, and water management. Intensive green roofs, on the other hand, are heavier systems with a diverse range of vegetation, including smaller trees and shrubs. They provide numerous benefits, including storm water storage, pollution reduction and biodiversity enhancement and often serve as multifunctional areas for activities like gardening and socialising. Constructed wet roofs combine the features of extensive green roofs and constructed wetlands for wastewater treatment. They temporarily retain storm water, reducing peak runoff flow, and are more physiologically active, especially in hot, dry periods, contributing to improved microclimate, air quality and biodiversity. The treated water from these roofs can also be reused, for instance, for irrigation or in toilets[38].

Boundary conditions - Limitations

- Flat or relatively flat rooftops with underground support structures are necessary
- Limited space for roots

Similar Terminology/Systems

- Rooftop Gardens
- Intensive roof
- Extensive roof
- Smart roof
- Constructed wet roof

More information:

- UNaLab: Nature-based Solutions Technical Handbook Factsheets
- GRÜNSTATTGRAU
- susdrain - sustainable drainage systems (SuDS)

[38] UNaLab, Nature-based Solutions Technical Handbook Factsheets, https://unalab.eu/en/documents/unalab-nbs-technical-handbook-factsheets

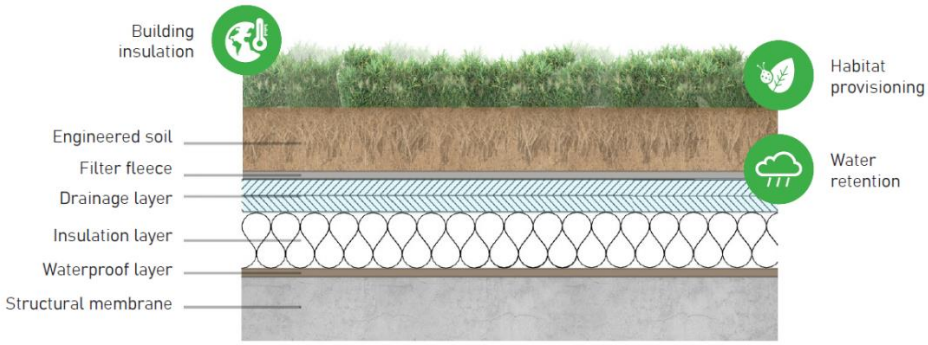


Figure 27: Typical layers of an extensive roof, ©UNaLab[39]

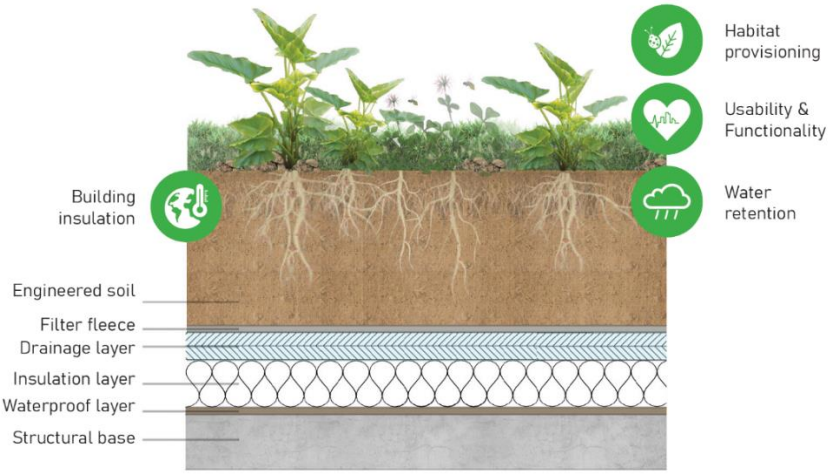


Figure 28: Typical layers of an intensive roof, ©UNaLab[40]

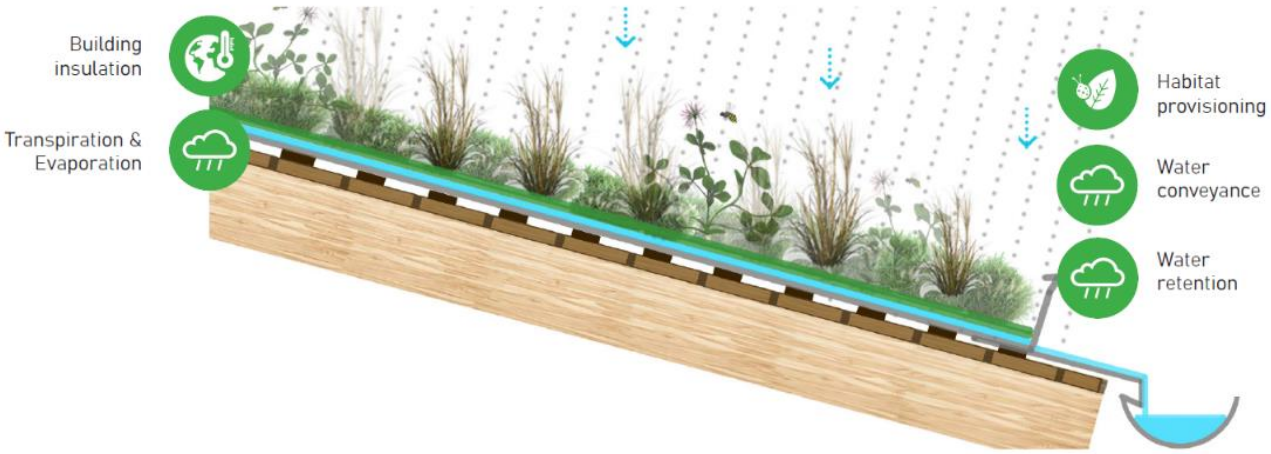


Figure 29: Typical layers of a constructed wet roof, ©UNaLab[41]

[39] handbook of UNaLab URBAN NATURE LABS, Institut für Landschaftsplanung und Ökologie, page 55
[40] handbook of UNaLab URBAN NATURE LABS, Institut für Landschaftsplanung und Ökologie, page 59
[41] handbook of UNaLab URBAN NATURE LABS, Institut für Landschaftsplanung und Ökologie, page 63

Figure 30: Extensive Green Roof combined with photovoltaics on a kindergarten, Bad Vöslau[42]

Figure 31: Intensive Green Roof on Bürgerhospital, Frankfurt[43]

[42] GRÜNSTATTGRAU Forschungs- und Innovations GmbH, https://gruenstattgrau.at/news/projekt/solargruendach-am-kindergarten/
[43] GRÜNSTATTGRAU Forschungs- und Innovations GmbH, https://gruenstattgrau.at/news/projekt/buergerhospital-frankfurt/

Table 5: Benefits of Green Roofs:

Floods (fluvial/pluvial)	Water Infiltration	+
	Water Retention	+
	Water Storage	+
Sediment/Mud	Erosion Prevention	
	Sediment/Mud Retention	
Drought	Water Reuse	+
	Keep Soil Moisture	
	Increase Groundwater Level	
Extra Services	Cooling	+
	Air Quality and Noise Reduction	+
	Biodiversity	+
	Beauty / Appearance	+

2.5.5. Rainwater Harvesting

Description

Rainwater harvesting is a process that involves collecting and storing rainwater from roofs and other hard surfaces for later use. This practice, traditionally involving the collection of rain from a roof into gutters that channel the water into downspouts and then into a storage vessel, can range from simple systems like water butts for garden use, to more elaborate setups that supply entire households. The systems, if designed appropriately, can also help reduce runoff rates and volumes. This practice offers triple benefits in urban areas: it reduces the costs of water infrastructure, decreases household expenditure on water when combined with water-efficient appliances, and lowers stormwater management costs. Despite the relative cost, maintenance and performance of small-scale systems like water butts being less than larger systems, they remain a common means of rainwater harvesting[44].

Boundary conditions - Limitations

- Systems can be complex and costly to install

Similar Terminology/Systems

- Roof water harvesting
- Rainwater storage
- Rainwater cistern
- Gaining water from rainfall
- Storm water harvesting
- Storm water reuse

More information:

- susdrain - sustainable drainage systems (SuDS)

[44] susdrain, https://www.susdrain.org/delivering-suds/using-suds/suds-components/source-control/rainwater-harvesting.html

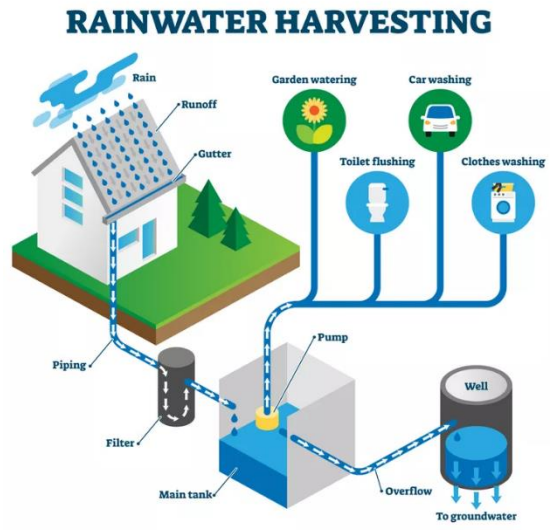


Figure 32: Rainwater Harvesting system diagram with hose roof water runoff, underground piping, filtering, and collecting in tank for domestic use[45]

Table 6: Benefits of Rainwater Harvesting:

Floods (fluvial/pluvial)	Water Infiltration	
	Water Retention	+
	Water Storage	+
Sediment/Mud	Erosion Prevention	
	Sediment/Mud Retention	
Drought	Water Reuse	+
	Keep Soil Moisture	
	Increase Groundwater Level	
Extra Services	Cooling	
	Air Quality and Noise Reduction	
	Biodiversity	
	Beauty / Appearance	

[45] A Beginner's Guide to Rainwater Harvesting, https://www.treehugger.com/beginners-guide-to-rainwater-harvesting-5089884

2.5.6. Rain Garden

Description

A rain garden concept is used in built-up, urban areas in a similar way to the sponge city concept, but it does not create a rootable pore system for trees. Trees are therefore not suitable for the rain garden system.

In urban areas, a rain garden is used for small-scale water management as a kind of urban infiltration basins (e.g. storage, infiltration). Often the run-off water from roofs, roads and other sealed surfaces is collected, discharged and infiltrated. In general, rain gardens should be planted with relatively dense, native vegetation that can withstand occasional flooding. Vegetation should also be selected specifically for each zone of the rain garden.

Rain gardens can also be combined with other water management solutions. A regular maintenance is required.

Boundary conditions - Limitations

- Not suitable for trees, sponge city concept can be used instead
- Native vegetation should be used
- Regular maintenance

Similar Terminology/Systems

- Swale-trench system
- Green streets
- Sustainable drainage systems (SuDS)
- Low impact development (LID)

More information:

- UNaLab: Nature-based Solutions Technical Handbook Factsheets
- susdrain - sustainable drainage systems (SuDS)

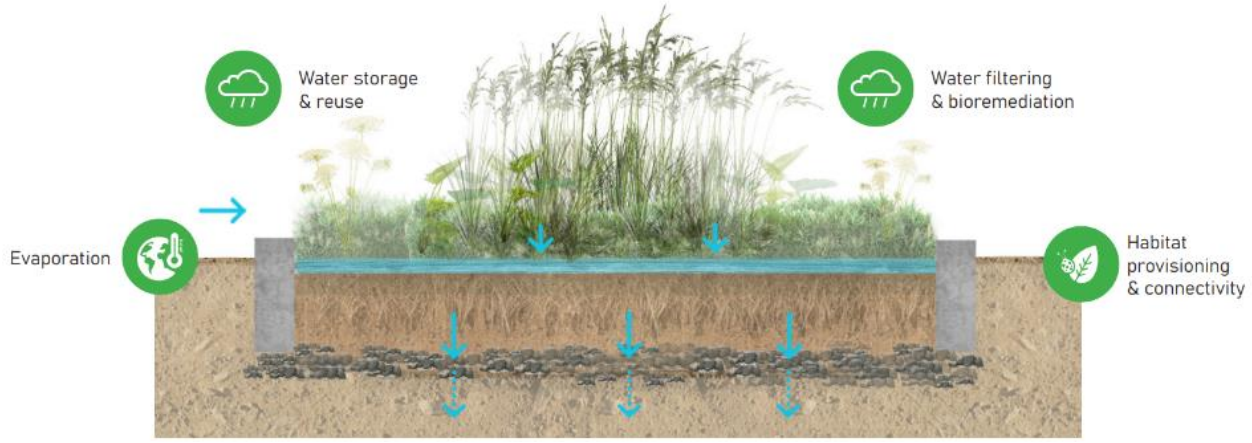


Figure 33: An example of a Rain Garden, ©UNaLab [46]

[46] handbook of UNaLab URBAN NATURE LABS, Institut für Landschaftsplanung und Ökologie, page 113

Figure 34: Rain Garden in Obergrafendorf (Lower Austria) and Graz, (Styria, Austria)[47]

Table 7: Benefits of Rain Garden:

Floods (fluvial/pluvial)	Water Infiltration	+
	Water Retention	+
	Water Storage	+
Sediment/Mud	Erosion Prevention	
	Sediment/Mud Retention	
Drought	Water Reuse	+
	Keep Soil Moisture	
	Increase Groundwater Level	+
Extra Services	Cooling	
	Air Quality and Noise Reduction	
	Biodiversity	+
	Beauty / Appearance	+

[47] Online: https://link.springer.com/article/10.1007/s00506-022-00914-0, 27.03.2024

2.5.7. Bioswale

Description

A bioswale is a vegetated, linear, and low-sloped structure often established in urban areas, near or between roads, with the objective to reduce flood risk during or after heavy rain events. The intention of bioswales is comparable to rain gardens. Bioswales absorb, store and convey surface water runoff, and remove pollutants and sediments as the water trickles through the vegetation and substrate layers. If properly planned and planted with native vegetation, a bioswale can contribute to local storm water management and can help support biodiversity[48].

Boundary conditions - Limitations

- Trees need to be managed or limited to allow water conveyance.
- The performance and acceptance of bioswales are dependent on regular and appropriate maintenance.

Similar Terminology/Systems

- Swale
- Grassed swale
- Vegetated filter strip
- Strip swale
- Open grassed ditches

More information:

- UNaLab: Nature-based Solutions Technical Handbook Factsheets
- susdrain - sustainable drainage systems (SuDS)

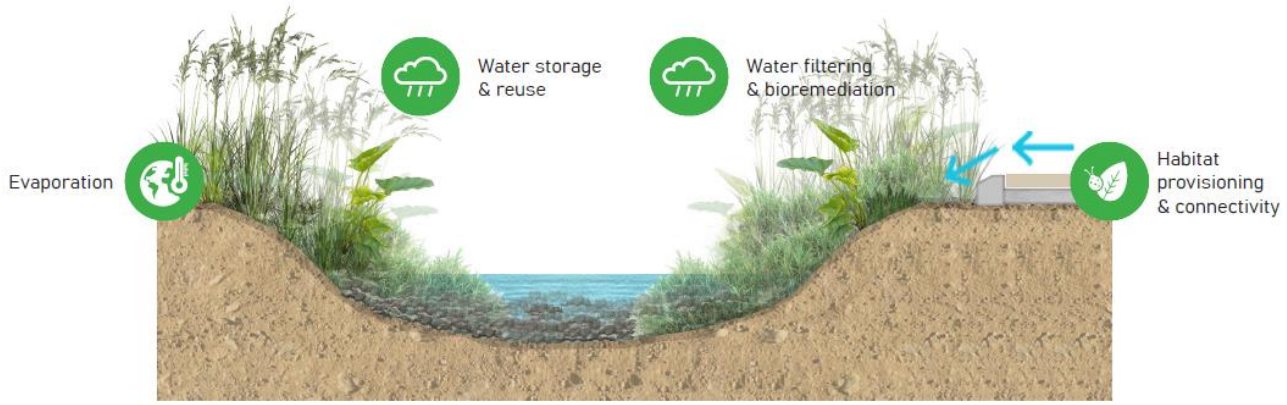


Figure 35: An example of a Bioswale and its associated natural processes and benefits, ©UNaLab[49]

[48] UNaLab, Nature-based Solutions Technical Handbook Factsheets, https://unalab.eu/en/documents/unalab-nbs-technical-handbook-factsheets

[49] handbook of UNaLab URBAN NATURE LABS, Institut für Landschaftsplanung und Ökologie, page 109

Figure 36: Bioswale Queen Mary's Walk, Llanelli[50]

Table 8: Benefits of a Bioswale:

Floods (fluvial/pluvial)	Water Infiltration	+
	Water Retention	+
	Water Storage	+
Sediment/Mud	Erosion Prevention	+
	Sediment/Mud Retention	+
Drought	Water Reuse	
	Keep Soil Moisture	
	Increase Groundwater Level	+
Extra Services	Cooling	+
	Air Quality and Noise Reduction	
	Biodiversity	+
	Beauty / Appearance	+

[50] susdrain: https://www.susdrain.org/case-studies/case_studies/queen_maryrs_walk_llanelli.html

2.5.8. Constructed Wetland

Description

Constructed wetlands are man-made wetland systems designed to collect, treat and store greywater or storm water runoff in urban areas. They mimic natural wetland processes, focusing on water purification and storage. Constructed wetlands can also enhance urban biodiversity by incorporating diverse vegetation and barrier free shores. They offer a cost-effective alternative to conventional wastewater treatment methods.

Typically, constructed wetlands are shallow basins filled with substrate, commonly sand or gravel, and planted with aquatic or semi-aquatic vegetation. They feature an inlet pipe for greywater or storm water runoff. The untreated water flows over or through the substrate layer and vegetation, undergoing natural filtration and cleaning. Equipped with an outlet for controlled water discharge, treated water often flows into another pond for storage. This treated storm water can be repurposed, such as for irrigation in green spaces.

Like constructed wetlands, alluvial meadows serve as areas for retaining runoff during heavy rain events. However, unlike the constructed wetlands, most of the time, when there is no rainfall, the meadows are dry.

Boundary conditions - Limitations

- Location outside of flood plains, upland with slope
- Enough space, appropriate soil conditions
- Implement water control measures
- Regular inspections, monitoring and maintenance

Similar Terminology/Systems

- Urban constructed wetland
- Constructed surface wetland
- Constructed marsh or reed bed
- Alluvial meadow
- Constructed floodplain

More information:

- UNaLab: Nature-based Solutions Technical Handbook Factsheets
- susdrain - sustainable drainage systems (SuDS)

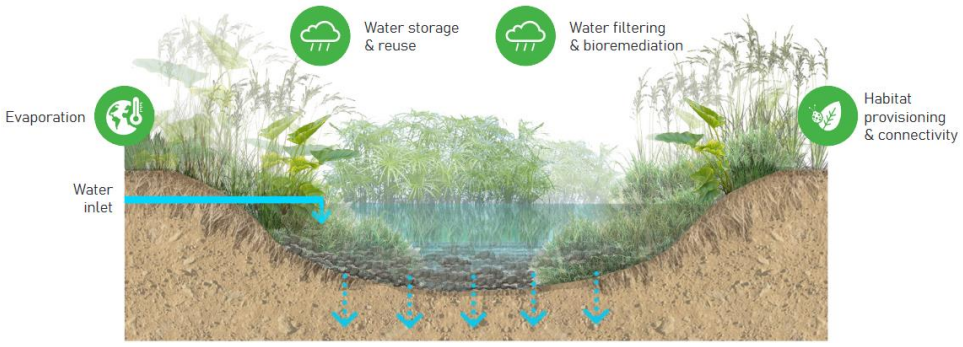


Figure 37: Example of a Constructed Wetland, ©UNaLab[51]

[51] handbook of UNaLab URBAN NATURE LABS, Institut für Landschaftsplanung und Ökologie, page 91

Figure 38: Alluvial meadow in Vuores area (https://unalab.eu/en)

Table 9: Benefits of Constructed Wetlands:

Floods (fluvial/pluvial)	Water Infiltration	+
	Water Retention	+
	Water Storage	+
Sediment/Mud	Erosion Prevention	
	Sediment/Mud Retention	+
Drought	Water Reuse	+
	Keep Soil Moisture	
	Increase Groundwater Level	
Extra Services	Cooling	+
	Air Quality and Noise Reduction	
	Biodiversity	+
	Beauty / Appearance	+

2.5.9. Infiltration Basin

Description

Infiltration Basins are flat, vegetated areas that are usually dry. After heavy rainfall, the water fills up the basin and soaks into the ground. Infiltration basins are usually built with the additional goal to recharge the water table, which differentiates them from retention basins in general. While often planted with grass, additional vegetation types can be integrated into infiltration basins, creating habitats for wildlife, thereby supporting biodiversity and improving aesthetic appeal[52].

Boundary conditions - Limitations

- Local soil conditions (e.g., permeability and infiltration capacity), available space, and highly specific rainwater intensities must be considered
- Can be integrated into private gardens, public green space, and driveways, but should not be directly connected to aquifers
- Trampling or any other soil compaction within infiltration basins should be avoided to ensure water infiltration capacity.

Similar Terminology/Systems

- Infiltration areas
- Infiltration planter
- Infiltration pond
- Recharge basin

More information:

- UNaLab: Nature-based Solutions Technical Handbook Factsheets
- susdrain - sustainable drainage systems (SuDS)

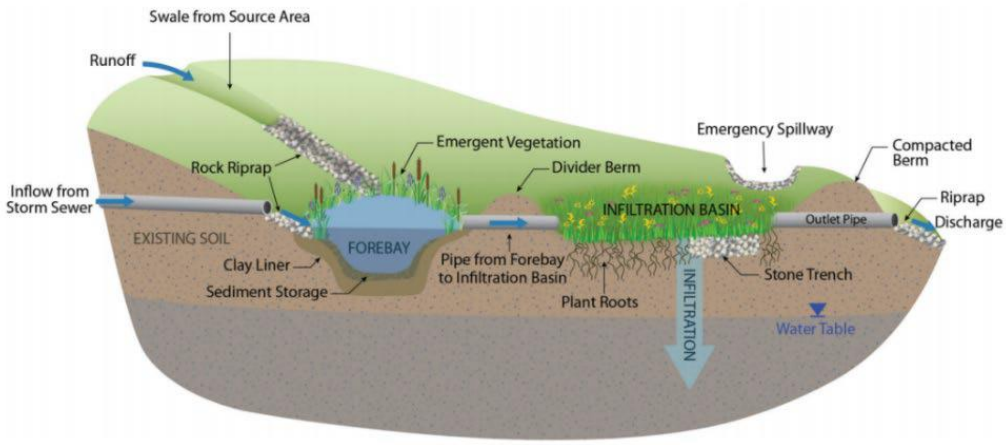


Figure 39: Infiltration Basin illustration (provided in: Massachusetts Department of Environmental Protection; geosyntec.com/)

[52] UNaLab, Nature-based Solutions Technical Handbook Factsheets, https://unalab.eu/en/documents/unalab-nbs-technical-handbook-factsheets

Figure 40: Infiltration Basin in Victoria Park Health Centre, Leicester[53]

Table 10: Benefits of an Infiltration Basin:

Floods (fluvial/pluvial)	Water Infiltration	+
	Water Retention	+
	Water Storage	
Sediment/Mud	Erosion Prevention	
	Sediment/Mud Retention	
Drought	Water Reuse	
	Keep Soil Moisture	
	Increase Groundwater Level	+
Extra Services	Cooling	
	Air Quality and Noise Reduction	
	Biodiversity	+
	Beauty / Appearance	+

[53] source: https://www.susdrain.org/case-studies/case_studies/victoria_park_health_centre_leicester.html

2.5.10. Retention and Detention Basin

Description

Detention basins are surface storage basins that retain storm water. During periods of heavy rain, the area gets flooded and could fill the detention basin for several days in cases of heavier or longer rainfall events. After the rain ends, the water flows in the sewer system or, ideally, infiltrates through the soil and recharges the groundwater. If there is no heavy rainfall event, the detention basins are dry and could be used as green areas.

Retention basins retain storm water continuously, holding water also in dry periods. They can also improve the water quality, for example, with downstream infiltration and sedimentation and provide habitat for aquatic and semi-aquatic species[54].

Boundary conditions - Limitations

- Usually requires a relatively large area.
- They could be considered in park planning

Similar Terminology/Systems

- Dry detention pond
- Dry detention basin
- Wet retention pond
- Wet retention basin
- Storm reservoir
- Storm-ponds

More information:

- UNaLab: Nature-based Solutions Technical Handbook Factsheets
- susdrain - sustainable drainage systems (SuDS)

Figure 41: Detention Basin (www.susdrain.org)

[54] UNaLab, Nature-based Solutions Technical Handbook Factsheets, https://unalab.eu/en/documents/unalab-nbs-technical-handbook-factsheets

Figure 42: Wet Retention Basin in Vuores, Tampere (source: City of Tampere)

Table 11: Benefits of a Retention and Detention Basin:

Floods (fluvial/pluvial)	Water Infiltration	
	Water Retention	+
	Water Storage	+
Sediment/Mud	Erosion Prevention	
	Sediment/Mud Retention	
Drought	Water Reuse	+
	Keep Soil Moisture	
	Increase Groundwater Level	
Extra Services	Cooling	+
	Air Quality and Noise Reduction	
	Biodiversity	
	Beauty / Appearance	+

2.5.11. Parks / Green Corridors

Description

Parks and Green Corridors are integral to the green infrastructure of cities, providing accessible spaces for nature interaction and recreation. Residential and urban parks, ranging from larger district parks with multifunctional uses to smaller elements like playgrounds and pocket parks, offer diverse green spaces within residential areas. Similarly, Green Corridors, transformed from derelict infrastructures like railway lines, contribute to the re-naturing of cities. These corridors, often regenerated along waterways and rivers, form linear parks that enhance accessibility to green spaces and promote sustainable transportation modes like walking and cycling. Both parks and green corridors support biodiversity by improving ecological networks and habitat connectivity, thereby playing a crucial role in urban sustainability[55].

Boundary conditions - Limitations

- New urban development areas allow for the establishment of residential parks at the most suitable location
- Spatially equal distribution of high-quality parks is important to maximise their impact on the urban climate, biodiversity, and residents

Similar Terminology/Systems

- Green areas, bushes, trees
- Urban park
- Pocket Park
- Parklet
- Linear park
- Green belts
- Green corridors

More information:

- UNaLab: Nature-based Solutions Technical Handbook Factsheets

Figure 43: Central Park in New York City (www.wikipedia.org)

[55] UNaLab, Nature-based Solutions Technical Handbook Factsheets, https://unalab.eu/en/documents/unalab-nbs-technical-handbook-factsheets

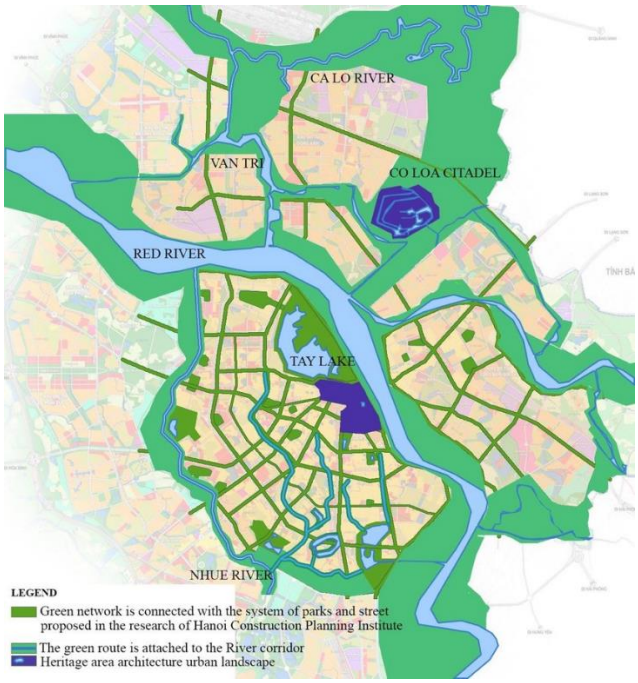


Figure 44: Structural Planning of the Urban Green Corridor for Hanoi City[56]

Table 12: Benefits of Parks and Green Corridors:

Floods (fluvial/pluvial)	Water Infiltration	+
	Water Retention	+
	Water Storage	
Sediment/Mud	Erosion Prevention	
	Sediment/Mud Retention	
Drought	Water Reuse	
	Keep Soil Moisture	+
	Increase Groundwater Level	+
Extra Services	Cooling	+
	Air Quality and Noise Reduction	+
	Biodiversity	+
	Beauty / Appearance	+

[56] https://www.researchgate.net/publication/350302728_Solutions_for_Structural_Planning_of_the_Urban_Green_Corridor_for_Hanoi_City

2.5.12. Increased Soil Shading

Description

The soil rich in moisture is not carried by the wind, so keeping soil moisture helps to prevent deflation. Shaded soil keeps the available water and saves it for later times. Shading can be achieved by (semi)natural vegetation, mulching, and as shading keeps soil temperature down, favours to wildlife and grown crops as well. Vegetated buffer strips help a lot in wind breaking. Constructed shading in settlements is also a good option.

Shading vegetation has additional positive impacts like slowing the wind, keeping evaporation down and keeping moisture-rich air on the site (operating the small water cycle).

Boundary conditions - Limitations

- Agriculture arable fields are highly exposed to deflation – without drastic change, this can not be decreased
- Vegetated buffer strips often considered as territory loss

Similar Terminology/Systems

- Forest gardening, agroforestry, permaculture
- Tree and bush stripes as windbreakers
- Mulching

More information:

- In farmlands: https://promar-international.com/7-tips-for-better-managing-soil-moisture-on-your-farm/

Figure 45: Shading in settlements[57]

[57] http://szepvilagunk.weebly.com/faacutek-viraacutegok/arnyas-allek-buvoleteben

Figure 46: Shading in the gardens[58]

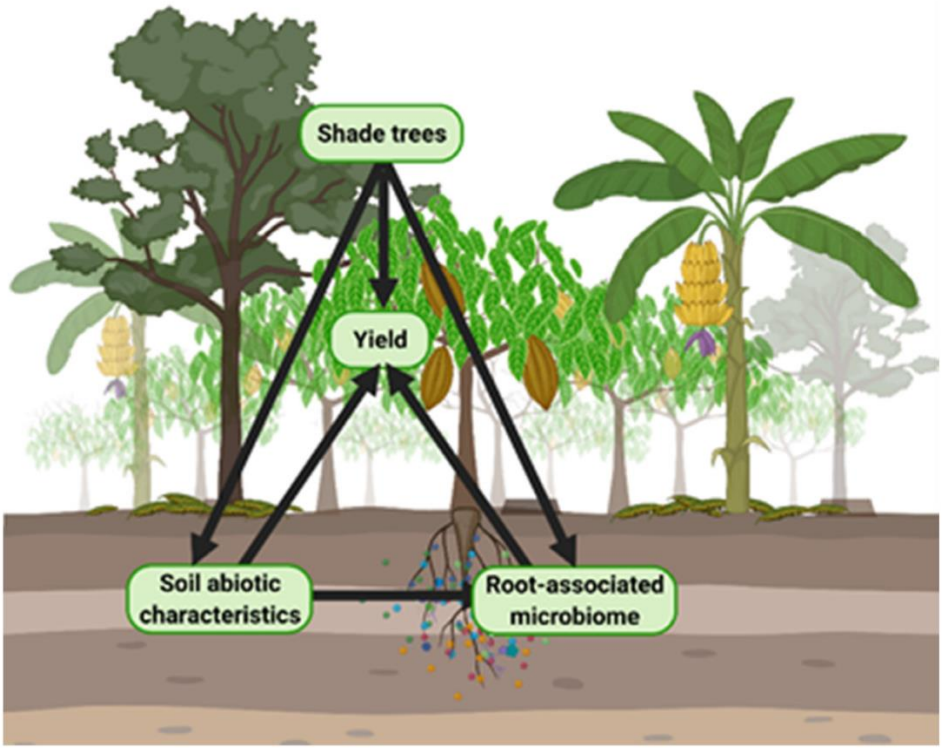


Figure 47: Hypothesized relationships of shade trees[59]

[58] https://www.thompson-morgan.com/plants-for-shade

[59] Jennifer E. Schmidt, ORCID,Alana Firl, Hamran Hamran, Nur Insana Imaniar, Taylor M. Crow and Samantha J. Forbes: Impacts of Shade Trees on the Adjacent Cacao Rhizosphere in a Young Diversified Agroforestry System, https://www.mdpi.com/2073-4395/12/1/195

Table 13: Benefits of Increased Soil Shading:

Floods (fluvial/pluvial)	Water Infiltration	
	Water Retention	+
	Water Storage	
Sediment/Mud	Erosion Prevention	+
	Sediment/Mud Retention	
Drought	Water Reuse	
	Keep Soil Moisture	+
	Increase Groundwater Level	
Extra Services	Cooling	+
	Air Quality and Noise Reduction	+
	Biodiversity	+
	Beauty / Appearance	+

2.5.13. Stream Daylighting

Description

Daylighting allows for the natural development of a water channel that fulfils the functions of a natural stream. This includes creating habitats for aquatic or semi-aquatic wildlife and vegetation, as well as enhancing the regulation and uptake of storm water runoff. Daylighting involves the opening or uncovering buried watercourses, like rivers and drainage systems, by removing concrete layers. This expands the river's space, increasing its storage capacity and reducing flood risk. It also promotes a more natural riverbed and riparian zone, improving aesthetics and supporting biodiversity.

Depending on what the intention of the project various designs are possible. For example, the completely culverted structure, or just parts of it like the top layer, may be removed or gaps could be created.

Boundary conditions - Limitations

- Costs for removing of infrastructure, especially in densely built areas
- Prior evaluation of the soil type under the channel and of the water quality/pollutant load
- Enough space available
- Connection to adjacent streams to allow for migration of water animals

Similar Terminology/Systems

- River daylighting
- Stream daylighting
- Culvert removal

More information:

- UNaLab: Nature-based Solutions Technical Handbook Factsheets
- https://www.frontiersin.org/articles/10.3389/fevo.2022.838794/full

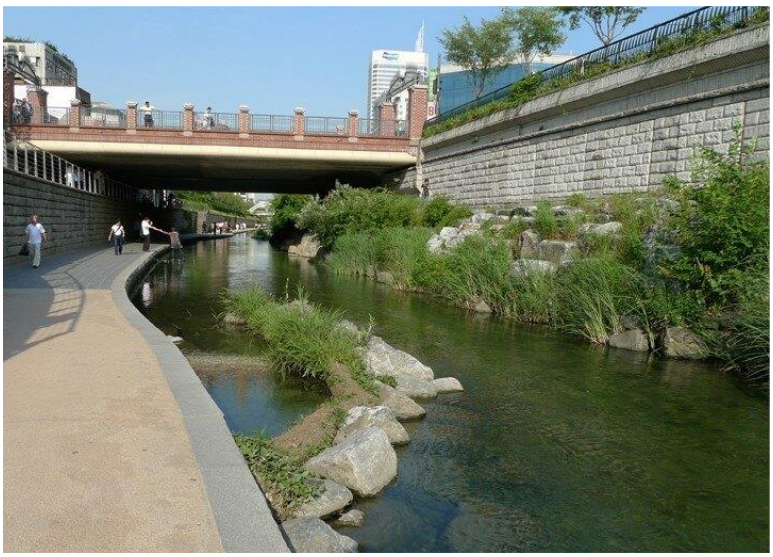


Figure 48: Cheonggyecheon stream in Seoul, one of the most successful daylighting projects[60]

[60] source: https://www.landscapeperformance.org/case-study-briefs/cheonggyecheon-stream-restoration-project

Figure 49: Left: Design typologies for deculverting, showing the generalised degrees of culvert removal and associated river restoration when daylighting.[61]. Right: Daylighted segment of De grote beek, Eindhoven, Netherlands[62]

Table 14: Benefits of Stream Daylighting:

Floods (fluvial/pluvial)	Water Infiltration	+
	Water Retention	
	Water Storage	
Sediment/Mud	Erosion Prevention	
	Sediment/Mud Retention	
Drought	Water Reuse	
	Keep Soil Moisture	
	Increase Groundwater Level	+
Extra Services	Cooling	+
	Air Quality and Noise Reduction	
	Biodiversity	+
	Beauty / Appearance	+

[61] Diagram by author, © 2013, Catchment Science Centre, University of Sheffield https://therivermanagementblog.wordpress.com/2013/03/11/what-to-do-with-lost-urban-rivers-beneath-our-feet/

[62] UNaLab, Nature-based Solutions Technical Handbook Factsheets, https://unalab.eu/en/documents/unalab-nbs-technical-handbook-factsheets , page 98

2.5.14. River Restoration

Description

River restoration aims to design rivers towards a more natural state, reinstating channels that fulfil important functions for the environment and public protection. The restored rivers are characterised by dynamic watercourses and sediment movements, aiding in storm water regulation, flood risk reduction, habitat provision and recreation. The restoration measures modify different parts of the river, including the riverbed, riverbank and floodplains, and range from small-scale to larger scale interventions. Techniques include the expansion of the flood plain area, channel widening and length extension, reprofiling the channel cross-section, introducing diverting and deflecting elements. These measures lead to flow variation, sediment shifting processes, structural remodelling, creating a more natural river appearance. They also provide space for human interaction and habitats for aquatic and small animals. The ultimate goal is to create a sustainable, functional and accessible river environment[63].

Boundary conditions - Limitations

- Infrastructure near the river or other types of land use can be seen as an limitation for river restoration

Similar Terminology/Systems

- Reprofiling
- "Side-pockets" (bays) for water storage, fish rest and spawning
- Channel widening and length extension
- Branches
- Re-curving river beds and canals
- Natural sediment movement
- Stream/river bed re-naturalisation
- Micro-relief in the river/streambed

More information:

- European Centre for River Restoration (ECRR)
- Manual of River Restoration Techniques
- UNaLab Nature Based Solutions – Technical Handbook Part II

Figure 50: New created branch for water retention, Neckar in Wernau/Neckar (www.pfrommer-roeder.de)

[63] UNaLab, Nature Based Solutions – Technical Handbook Part II, https://errin.eu/documents/unalab-technical-handbook-nature-based-solutions

Figure 51: Restoration and flood protection project "Streams of Graz", Graz[64]

Table 15: Benefits of River Restoration:

Floods (fluvial/pluvial)	Water Infiltration	+
	Water Retention	+
	Water Storage	
Sediment/Mud	Erosion Prevention	
	Sediment/Mud Retention	+
Drought	Water Reuse	
	Keep Soil Moisture	
	Increase Groundwater Level	+
Extra Services	Cooling	+
	Air Quality and Noise Reduction	
	Biodiversity	+
	Beauty / Appearance	+

[64] source: https://www.graz.at/cms/beitrag/10396383/8028812/Grazer_Baeche_im_Ueberblick.html

2.5.15. Living Embankment

Description

Living embankments, a form of bioengineering, utilise techniques like living fascines, revetments with cuttings, and planted embankment mats to stabilise riverbanks and hills. Living fascines use bundles of living wood, providing habitats for plants and animals, and enhancing biodiversity. They offer superior stabilisation as plants develop from the living wood and roots provide soil protection. Revetments with cuttings cover eroded riverbanks with root-able plants like willow, leading to long-term stabilisation by allowing natural re-cultivation of plants. Planted embankment mats combine biodegradable mats with a vegetation layer, reducing water velocity, promoting sedimentation, and preventing erosion. As the vegetation develops strong root networks, it supports long-term erosion prevention and promotes biodiversity[65].

Boundary conditions - Limitations

- Good timing for construction (e.g., low water flow, no rainfall) and planting is necessary.
- Stability of the river bank is difficult to calculate and foresee.

Similar Terminology/Systems

- Living Fascine
- Vegetated erosion-control mat
- Vegetated erosion-control blanket
- Living Shoreline
- Planted embankment mat

More information:

- UNaLab: Nature-based Solutions Technical Handbook Factsheets

Figure 52: Planted embankment mat[66]

[65] UNaLab, Nature-based Solutions Technical Handbook Factsheets, https://unalab.eu/en/documents/unalab-nbs-technical-handbook-factsheets

[66] source: Jany, Angelika and Peter Geitz 2013, Ingenieurbiologische Bauweisen an Fließgewässern, Teil 2

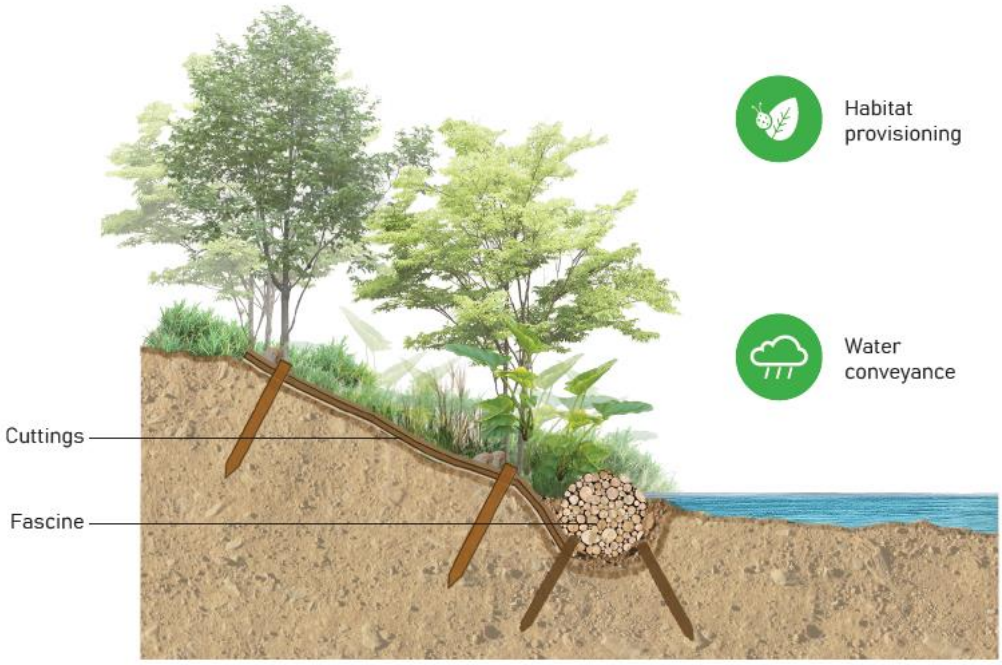


Figure 53: An example of a revetment with cuttings combined with a fascine, ©UNaLab[67]

Table 16: Benefits of a Living Embankment:

Floods (fluvial/pluvial)	Water Infiltration	+
	Water Retention	+
	Water Storage	
Sediment/Mud	Erosion Prevention	+
	Sediment/Mud Retention	+
Drought	Water Reuse	
	Keep Soil Moisture	+
	Increase Groundwater Level	
Extra Services	Cooling	+
	Air Quality and Noise Reduction	
	Biodiversity	+
	Beauty / Appearance	+

[67] handbook of UNaLab URBAN NATURE LABS, Institut für Landschaftsplanung und Ökologie, page 41

2.5.16. Leaky Dams

Description

Leaky Dams are flood prevention tools to slow the flow and as retaining water, cutting the flood peak. Barriers are built from natural material, most often from tree branches and the holding structure from thick branches or tree trunks. Their important characteristic is that they let certain part of the water through all the time: the whole water amount during low water season, and the same amount in high water season, while retained water flows down gradually, extended in time. This way the longitudinal connectivity is provided continuously. Leaky dams have a positive impact on ecology, which may meet land use preferences as well: the retained water is partly taken up by the soil, preserved for the dry period after the flood, and provides soil moisture for both natural habitats and agricultural fields. Moreover, retained water may create new wetland habitats, similar to the "natural pair" of leaky dams, the beaver-dams.

Boundary conditions - Limitations

- Not realistic to use on large rivers, only on their smaller tributaries.
- Natural biodegradation breaks it down in appr. 10 years, though with proper site management, the newly built ones take the role of old ones over (many leaky dams applied together can have considerable result).

Similar Terminology/Systems

- Coarse woody debris ponds
- Large woody debris dams
- Leaky barriers
- Beaver-dam

More information:

- https://www.stroud.gov.uk/environment/flooding-and-drainage/stroud-valleys-natural-flood-management-project

Figure 54: Stroud Rural Sustainable Drainage Project[68]

[68] Chris Uttley, Stroud District Council, Stroud Rural Sustainable Drainage Project: https://www.bathnes.gov.uk/sites/default/files/stroud_rural_suds.pdf

Figure 55: Leaky Dam in Püspökszilágy, Hungary

Table 17: Benefits of Leaky Dams:

Floods (fluvial/pluvial)	Water Infiltration	
	Water Retention	+
	Water Storage	+
Sediment/Mud	Erosion Prevention	+
	Sediment/Mud Retention	+
Drought	Water Reuse	
	Keep Soil Moisture	+
	Increase Groundwater Level	+
Extra Services	Cooling	+
	Air Quality and Noise Reduction	
	Biodiversity	+
	Beauty / Appearance	

2.5.17. Re-connected Floodplains

Description

Reconnected floodplains are a crucial aspect of riverine environments, often restored to mitigate the effects of previous disconnections and drainages implemented for housing protection, agriculture or development. These disconnections may accelerate water flow through a catchment, increasing downstream flood risks. The accelerated water flow also lead to riverbed deepening and subsequently to a drop in the groundwater level in the surrounding area. Restoration involves breaching or setting back flood banks at strategic locations, allowing water to spill onto the floodplain, thereby recreating its natural state. This process expands the floodplain area by excavating the lateral river bed, providing additional flood space for water control and management. The newly created, relatively flat and accessible areas can serve public purposes like relaxation and leisure activities or agricultural purposes during low water levels. The benefits of such reconnection are manifold, including increased flood storage area, recreation of wetland habitats, reintroduction of wetland species, and creation of fish refuges during high flows. Thus, reconnected floodplains play a pivotal role in enhancing biodiversity, managing flood risks, and providing community spaces[69].

Boundary conditions - Limitations

- Infrastructure near the river or other types of land use can be seen as a limitation for extending floodplains
- Availability of sufficient land

Similar Terminology/Systems

- Re-activating former floodplains
- Restoring peatlands
- Extending flood plain area
- Setback levees
- Floodplain meadows

More information:

- European Centre for River Restoration (ECRR)
- Manual of River Restoration Techniques
- UNaLab Nature Based Solutions – Technical Handbook Part II

[69] UNaLab, Nature Based Solutions – Technical Handbook Part II, https://errin.eu/documents/unalab-technical-handbook-nature-based-solutions

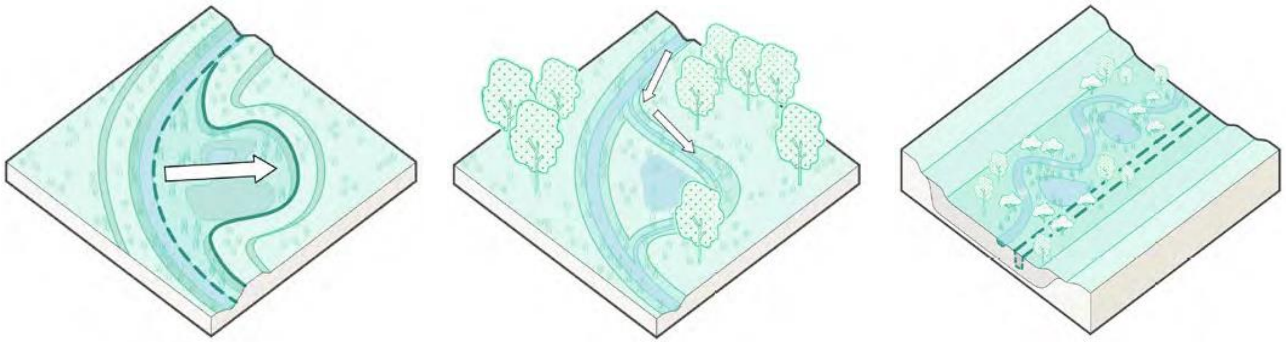


Figure 56: Left: setting levees back, middle: river bypass, Right: re-activating the floodplain, © World Bank [70]

Figure 57: Donau-Auen National Park, Riverine Wetlands National Park, Austria (https://www.donauauen.at/en)

[70] World Bank, Washington, DC. A Catalogue of Nature-Based Solutions for Urban Resilience http://hdl.handle.net/10986/36507

*Figure 58: Extended flood plain area (*https://www.landsrl.com/)

Table 18: Benefits of Re-connected Floodplains:

Floods (fluvial/pluvial)	Water Infiltration	+
	Water Retention	+
	Water Storage	
Sediment/Mud	Erosion Prevention	
	Sediment/Mud Retention	+
Drought	Water Reuse	
	Keep Soil Moisture	+
	Increase Groundwater Level	+
Extra Services	Cooling	+
	Air Quality and Noise Reduction	+
	Biodiversity	+
	Beauty / Appearance	+

2.5.18. Protective Forests and Wetlands

Description

Protective forests and wetlands are vital natural resources that serve as safeguards against various natural hazards. Protective forests primarily mitigate the impact of hazards like rock falls, avalanches, erosion, landslides, and flooding in mountainous regions. They cover sloping areas between potential hazards and endangered assets, playing a crucial role in soil protection and erosion prevention. Their preservation is an important investment for the habitability and development of mountain areas.

Wetlands, encompassing marshes, swamps, bogs, and fens, provide numerous beneficial services. They protect and improve water quality, provide habitats for fish and wildlife, and store floodwaters, maintaining surface water flow during dry periods. Wetlands act as natural reservoirs, temporarily holding excess floodwaters during high runoff conditions. Wetlands act as natural reservoirs that temporarily retain excess floodwater during high runoff conditions. They release the stored water only gradually, effectively decreasing downstream flooding and erosion intensity. Both protection forests and wetlands are essential for environmental health and resilience.

Boundary conditions - Limitations

- Infrastructure near the protective forests and wetlands or other types of land use can be seen as a limitation

Similar Terminology/Systems

- Restoring and protecting forests and wetlands
- Reforestation
- Continuous forest cover
- Natural Forest Rehabilitation
- Marshes
- Swamps
- Bogs
- Fens

More information:

- European Centre for River Restoration (ECRR)
- Manual of River Restoration Techniques
- Ramsar international - The Convention on Wetlands

Figure 59: Wetlands in the Rabensburger Thayaauen nature reserve[71]

[71] https://www.naturland-noe.at/naturschutzgebiet-rabensburger-thaya-auen

Figure 60: Protective forest, Austria[72]

Table 19: Benefits of Protective Forests and Wetlands:

Floods (fluvial/pluvial)	Water Infiltration	+
	Water Retention	+
	Water Storage	+
Sediment/Mud	Erosion Prevention	+
	Sediment/Mud Retention	+
Drought	Water Reuse	
	Keep Soil Moisture	+
	Increase Groundwater Level	+
Extra Services	Cooling	+
	Air Quality and Noise Reduction	+
	Biodiversity	+
	Beauty / Appearance	+

[72] https://www.protective-forest.at/content/whatisaprotectiveforest.html

2.5.19. Agricultural Management Changes

Description

Changes in agricultural management, which help build up soil health, can help improve soil and water retention on the fields, while also supporting agricultural production and offering nature-based solutions to climate adaptation.

Measures, such as reduced tillage, reduction of subsoil compaction, increase of soil organic matter, and keeping the soil covered by cover crops, mulch or crop residues help to reduce soil erosion, retain rainwater, increase infiltration and soil water storage, thereby addressing the impacts of both heavy rainfall and drought.

Contour farming and implementation of micro-dams between ridges of e.g. potato fields lowers soil erosion risk by reducing the flow of water and sediment within the field.

Boundary conditions - Limitations

- Farmer involvement is key, privately owned land
- Available subsidy programmes to support and motivate implementation

Similar Terminology/Systems

- Continuous soil coverage
- Mulching, crop residue management
- Cover cropping
- Second-crop
- Crop change
- Reduced tillage
- Micro-dams between ridges
- Contour-farming
- Reduction of subsoil compaction
- Increase of soil organic matter
- Agro-ecology, permaculture

More information:

- https://www.naturebasedsolutionsinitiative.org/wp-content/uploads/2021/10/nature-based-solutions-adaption-report.pdf

Figure 61: Micro-dams between ridges in a potato field, ©BAW-IKT

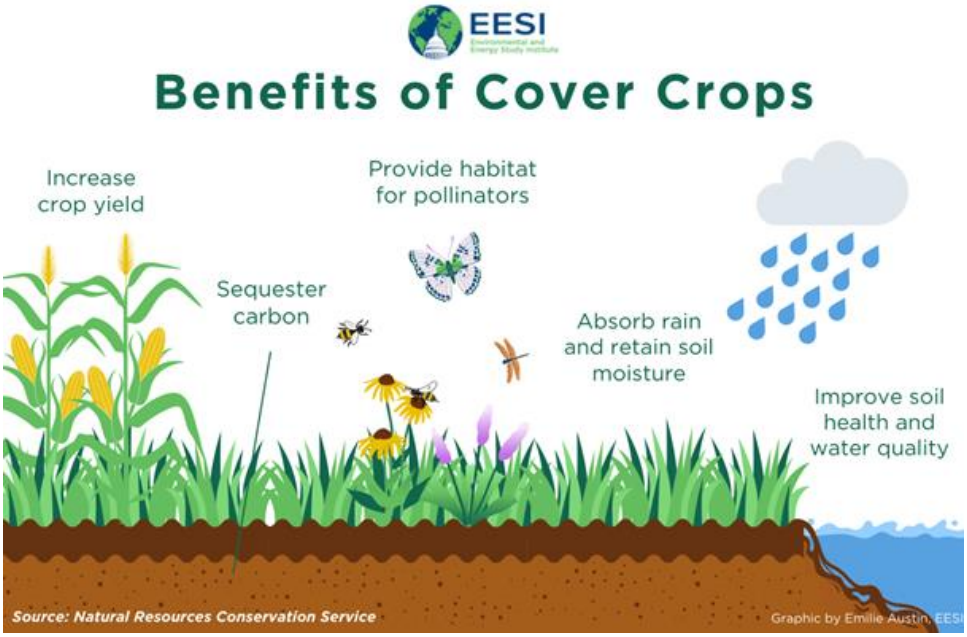


Figure 62: Benefits of cover crops[73]

Table 20: Benefits of Agricultural Management Changes:

Floods (fluvial/pluvial)	Water Infiltration	+
	Water Retention	+
	Water Storage	
Sediment/Mud	Erosion Prevention	+
	Sediment/Mud Retention	+
Drought	Water Reuse	
	Keep Soil Moisture	+
	Increase Groundwater Level	
Extra Services	Cooling	
	Air Quality and Noise Reduction	
	Biodiversity	+
	Beauty / Appearance	

[73] https://www.eesi.org/articles/view/cover-crops-for-climate-change-adaptation-and-mitigation

2.5.20. Landscape Structure and Buffering Measures

Description

It is important to consider how the different landscape elements (fields, forest, watercourses, natural habitats and infrastructure) are situated according to each other and how this affects water and sediment flow in the landscape. Diversity in land use forms may help to prevent the flow of water and sediment down-stream, as can targeted NBS installed at appropriate sites.

Buffering measures such as vegetated buffer strips, grassed waterways, hedgerows or sediment traps are designed to either reduce runoff, thereby preventing erosion or trap sediment once erosion already occurred. They are typically placed at field margins or in thalwegs and help to reduce sedimentation of watercourses.

Sediment retention basins function more as mitigation measures if erosion could not be prevented by other measures. They can be situated near a soil erosion hotspot to trap the water and sediment flow. Through proper design such basins could also be used as water retention basins, where the water can be re-used e.g. on agricultural fields.

Nature-based structures in the landscape such as species-rich buffer strips and hedges can also attribute to biodiversity improvements by providing habitat for pollinators and natural pest predators, thereby also helping to combat increased pest pressures in a changing climate[74].

Boundary conditions - Limitations

- Buffering measures which trap sediment may let water run through, thereby not reducing flood risk
- Connectivity between different landscape elements should be considered – one buffer strip won't do it alone; a holistic landscape approach should be considered to tackle the relevant water and sediment management issues in your area

Similar Terminology/Systems

- Buffer strips
- Grassed waterways
- Terracing
- Shelterbelts/windbreaks/hedgerows/field margins
- Tree and bush stripes
- Vegetative barriers
- Sediment traps
- Sediment retention basin
- Diversity in land use forms

More information:

- https://www.naturebasedsolutionsinitiative.org/wp-content/uploads/2021/10/nature-based-solutions-adaption-report.pdf

[74] https://www.naturebasedsolutionsinitiative.org/wp-content/uploads/2021/10/nature-based-solutions-adaption-report.pdf

Figure 63: Vegetative barrier with bushes and grass at the edge of a field, ©BAW-IKT

Figure 64: Grassed waterway implemented at known erosion hotspot, ©BAW-IKT

Table 21: Benefits of Landscape Structure and Buffering Measures:

Floods (fluvial/pluvial)	Water Infiltration	+
	Water Retention	+
	Water Storage	
Sediment/Mud	Erosion Prevention	+
	Sediment/Mud Retention	+
Drought	Water Reuse	
	Keep Soil Moisture	+
	Increase Groundwater Level	
Extra Services	Cooling	
	Air Quality and Noise Reduction	
	Biodiversity	+
	Beauty / Appearance	+

2.5.21. Land Conversion

Description

Land conversion from one land use to another based on what the land is suitable for or how it can best contribute to climate change adaptation can also be considered an NBS. For example, conversion of arable land to forest, permanent grassland or changing the farming system can reduce soil erosion, increase water infiltration and retention and provide other additional benefits such as habitat and recreational areas. By letting intensively used landscapes revert to a more natural state such as in the case of e.g. peatland and wetland restoration or river re-naturalisation a wide range of water and sediment related adaptation benefits can be gained.

Agroforestry is a farming method, which integrates trees, crops and animals to create productive and resilient ecosystems. Trees can enhance soil infiltration rates and water storage capacity, reducing the impact of both periods of too much and too little water. Additional benefits of agroforestry include enhanced fertility due to the incorporation of organic matter from leaf litter and roots, increased biodiversity and a diversified income source for farmers with the sale of fruit, nuts or timber[75].

Boundary conditions - Limitations

- Intelligent policy design and landscape planning is needed to avoid possible trade-offs

Similar Terminology/Systems

- Land-use change
- Afforestation
- Re-introduce traditional land use forms
- Permanent grassland and set-aside
- Perennial crops, crop diversification
- Agroforestry, forest gardening
- Peatland or wetland restoration

More information:

- https://www.naturebasedsolutionsinitiative.org/wp-content/uploads/2021/10/nature-based-solutions-adaption-report.pdf

Figure 65: Active peat extraction next to natural peatland, ©BAW-IKT

[75] https://www.naturebasedsolutionsinitiative.org/wp-content/uploads/2021/10/nature-based-solutions-adaption-report.pdf

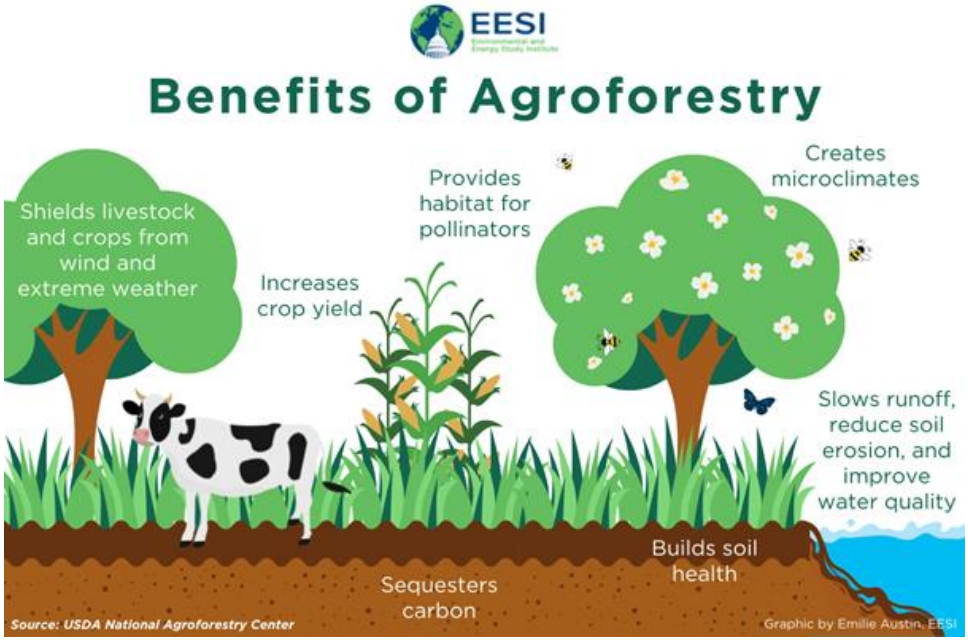


Figure 66: The benefits of agroforestry[76]

Table 22: Benefits of Land Conversion:

Floods (fluvial/pluvial)	Water Infiltration	+
	Water Retention	+
	Water Storage	+
Sediment/Mud	Erosion Prevention	+
	Sediment/Mud Retention	+
Drought	Water Reuse	
	Keep Soil Moisture	+
	Increase Groundwater Level	
Extra Services	Cooling	
	Air Quality and Noise Reduction	
	Biodiversity	+
	Beauty / Appearance	+

[76] https://www.eesi.org/articles/view/qa-how-the-savanna-institute-is-helping-agroforestry-thrive-in-the-midwest

Table 23: NBS overview used in this textbook

	Floods (fluvial/pluvial)			Sediment/Mud		Drought			Extra Services			
	Water Infiltration	Water Retention	Water Storage	Erosion Prevention	Sediment / Mud Retention	Water Reuse	Keep Soil Moisture	Increase Groundwater Level	Cooling	Air Quality and Noise Reduction	Biodiversity	Beauty / Appearance
Land Conversion	+	+	+	+	+		+				+	+
Landscape Structure and Buffering Measures	+	+		+	+		+				+	+
Agricultural Management Changes	+	+		+	+		+				+	
Protective Forests and Wetlands	+	+	+	+	+		+	+	+	+	+	+
Re-connected Floodplains	+	+			+		+	+	+	+	+	+
Leaky Dams		+	+	+	+		+	+	+		+	
Living Embankment	+	+		+	+		+		+		+	+
River Restoration	+	+			+			+	+		+	+
Stream Daylighting	+							+	+		+	+
Increased Soil Shading		+		+			+		+	+	+	+
Parks / Green Corridors	+	+					+	+	+	+	+	+
Retention and Detention Basin		+	+			+			+			+
Infiltration Basin	+	+						+			+	+
Constructed Wetland	+	+	+		+	+			+		+	+
Bioswale	+	+	+	+	+			+	+		+	+
Rain Garden	+	+	+			+		+			+	+
Rainwater Harvesting		+	+			+						
Green Roofs	+	+	+			+			+	+	+	+
Street Trees	+	+						+	+	+	+	+
Sponge City Concept	+	+						+	+	+	+	+
Permeable Paving System	+	+						+	+			

3. Making it happen: an NBS-Action Plan

This section applies the knowledge acquired in previous chapters about the benefits and possibilities of Nature-Based Solutions (NBS) to local conditions. The fundamental steps for implementing an NBS project will be discussed first. Subsequently, parts of these project steps will be worked on interactively, culminating in a collaboratively developed action plan. This plan will be pursued further with all involved stakeholders, guided by recommendations.

To begin with, it is essential to grasp the fundamentals of project development. This includes defining the problem, identifying stakeholders, conducting variant studies, and exploring implementation possibilities.

During the interactive part, we will focus on individual steps of project development. We will commence by identifying areas in the local environment, such as villages, municipalities, and regions, where there is a requirement for water and sediment retention. An action plan will be collectively developed based on this collection. This can be done using planning documents/maps or through a site visit.

Finally, we will discuss potential challenges and explore possibilities for monitoring the measures. This approach ensures that the action plan is comprehensive, robust, and adaptable to changing circumstances and needs.

3.1. Developing a Nature-Based Solution (NBS) project

Creating an NBS project involves three main stages[77]:

- **Planning**: Define the project's goals and design approach.
- **Execution**: Develop a detailed design and implement it.
- **Delivery**: Operate, maintain, and monitor the project.

These stages are not strictly linear; they can cycle back and forth as needed. Now, let's break down the stages into simpler steps according to Figure 67.

[77] Somarakis, G., Stagakis, S., & Chrysoulakis, N. (Eds.). (2019). Thinknature Nature-Based Solutions Handbook. ThinkNature project funded by the EU Horizon 2020 research and innovation programme.

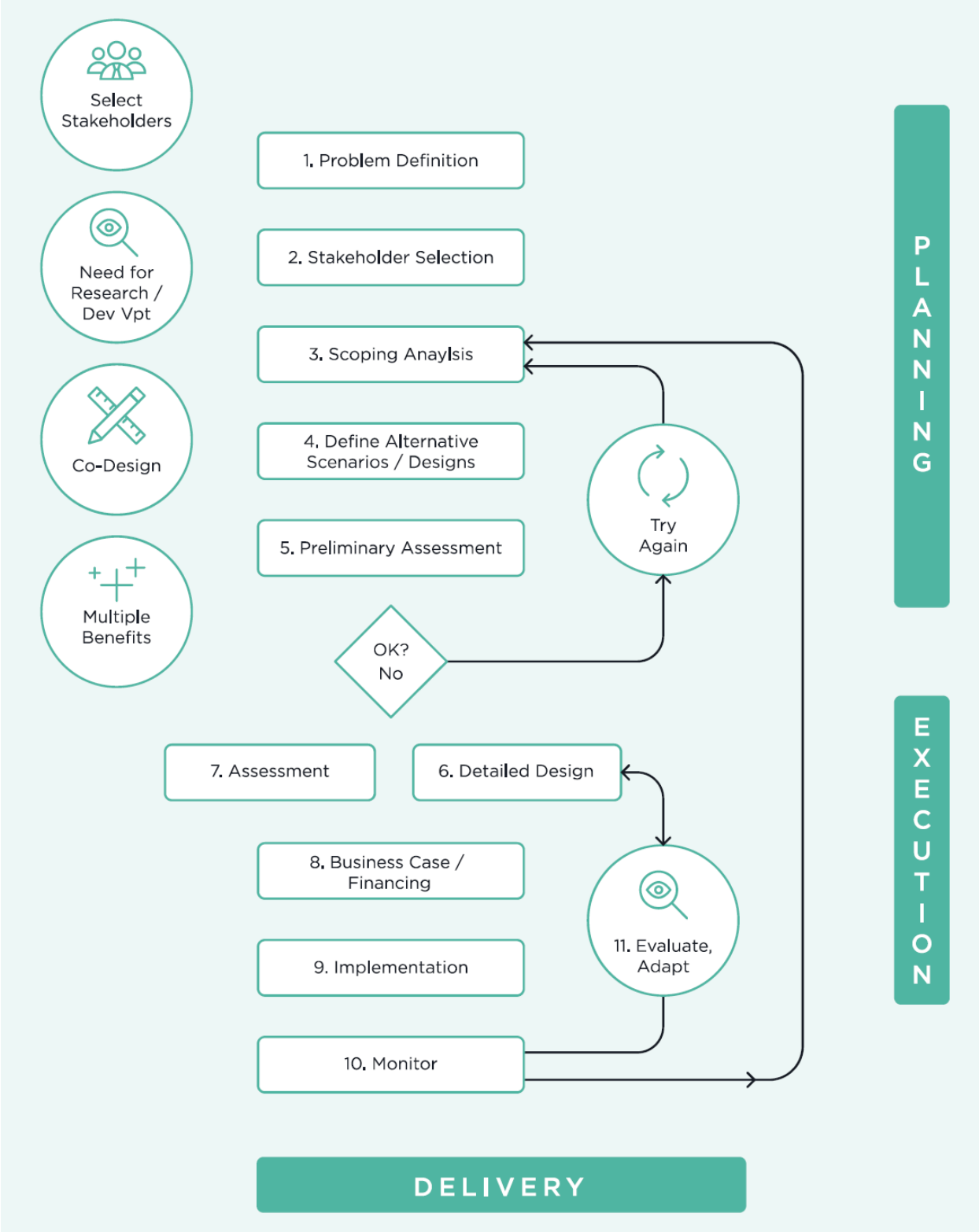


Figure 67: Implementation logic for NBS[78]

[78] Somarakis, G., Stagakis, S., & Chrysoulakis, N. (Eds.). (2019). Thinknature Nature-Based Solutions Handbook. ThinkNature project funded by the EU Horizon 2020 research and innovation programme.

3.1.1. Practical guide

Step 1: Define the Problems and Needs

Identify the challenges that need a solution. The scale of the problem will determine the scale of the NBS. For example, river flooding is a large-scale problem, while urban flooding is a smaller-scale issue. A project sponsor, such as a local authority, citizen group, NGO, or developer, can help define the problem and suggest actions.

Step 2: Select Stakeholders

Identify everyone who will be involved in or affected by the project. This includes people directly involved in planning and implementing the project, as well as those who will use or be affected by it. Stakeholders can include politicians, public agencies, scientists, institutions, experts, communities, Non-Governmental Organisations, landowners and developers, firms, and more. If there is resistance to the project, it can be managed through collaboration, information sharing, and strong communication.

Key points for stakeholder involvement:

- 'Stakeholders' refers to everyone who has a stake in any aspect of your activities. Think broadly, about who will be affected or have an interest.
- Well-planned and inclusive engagement leads to better outcomes.
- Start by identifying your stakeholders and then analyse their needs, interests, and preferences.
- Engagement should be participatory, inclusive, and tailored to each stakeholder group. This ensures that everyone's voice is heard and their needs are considered.

Step 3: Conduct a Scoping Analysis

Document the problems the NBS should solve, the challenges it should meet, and the aims it should fulfil. Make realistic estimates of the resources needed, the timeline, the required expertise, and any legislative requirements. This includes understanding if permits are required, if public procurement is needed, and if there are specific norms or standards that apply.

Step 4: Develop Multiple Scenarios

Create several preliminary designs or scenarios for the project. For simple NBS projects, all stakeholders can be involved. For more complex ones, a team of experts should outline the alternatives.

Step 5: Conduct a Preliminary Assessment

Evaluate the preliminary designs and select the most promising solution. Remember, NBS projects aim to target different goals simultaneously. So, involve all stakeholders in listing the expected benefits and constraints of each design. These benefits can be environmental, social, or economic.

Step 6: Develop a Detailed Design

Once the preferred preliminary design is selected, develop a detailed design. The level of detail needed depends on the type of NBS. For example, a simple cover cropping project needs less detail than a complex project to reconnect floodplains in a river basin.

Step 7: Conduct a Detailed Assessment

Carry out a more detailed assessment of the environmental and financial aspects of the project. This step is especially important for complex and large-scale projects where permits and financing need to be addressed.

Step 8: Develop a Business Case and Secure Financing

Based on the assessment in step 7, develop a detailed business case. Consider questions like: Is the project public or private? Is a public procurement process necessary? Can private financing be found? Who will benefit from the NBS? If third parties also benefit, are they willing to pay for these benefits? Is a public-private partnership an option? What other resources are needed to realise the project?

Step 9: Implementation

This step involves building or realising the detailed design. The specifics, like schedule, project management, and resources, depend on the scale, type, and location of the NBS project.

Step 10: Monitoring

After the NBS is implemented, it is important to monitor its functioning and evolution. This involves selecting and designing robust monitoring methodologies. The choice of monitoring methodologies depends on various factors, including performance goals, the type of NBS, the scale of implementation, the expected impacts and benefits, and the resources available for monitoring.

Step 11: Evaluation / Adaptation

Nature-based projects are dynamic, so it is possible that the design objectives might not be completely achieved. If this happens, the feedback information can be used to revisit the scoping analysis (step 3) or the detailed design (step 6) in an iterative cycle. This allows necessary or possible adjustments to meet the main NBS objectives. This iterative process is a form of adaptive management.

3.2. Assessment of local water retention and sediment management needs

Required Materials: Local maps, aerial photos, if available hazard zone plans, slope water maps and sticky notes

Using maps, aerial photos, or hazard zone plans, participants should identify locations where, based on their experience, there are problems with water or sediment (according to Step 1: Define the Problems and Needs), or derive possible hotspots from the documents. As a stimulus, participants should deal with the following questions:

Floods:

- Where does the local stream/river overflow during heavy rainfall?
- Where does water stand on the street when it rains?
- Where does water stand on meadows/fields during heavy rain?
- Where do small, rushing streams form when it rains?
- Are there any areas where human intervention has significantly altered the natural water flow?
- Are there any areas that have been identified as flood risk zones?

Sediment/Mud:

- Where does brown water (rich in sediment) run over the street during heavy rain?
- How does a rain event lead to mud/sediment deposits?
- Where is the top layer of soil missing after rain, revealing deeper soil layers?
- Are there any areas that are prone to landslides or soil erosion?
- Are there any areas that have been heavily deforested or where vegetation has been significantly reduced?

Droughts:

- Where do soils crack completely due to drying out?
- Where do bushes and trees dry out?
- Are there any particularly large, sealed surfaces that feel unbearably hot in summer (car parks, squares, etc.)?

3.3. Action Plan

Based on the previously identified needs/problems and the knowledge of Nature-Based Solutions (NBS) gained in the previous chapters, an action plan will be designed (according to Step 4: Develop Multiple Scenarios). Depending on local conditions (small community, large region) or time constraints (duration of the training), two variants can be implemented: either a local walk to explore possible implementations directly on site, or possible implementations can be developed using the maps, aerial photos, and hazard zone plans from before. The advantage of the latter variant is that a larger area can be covered, which might be too large for a walk. Also, different areas can be worked on simultaneously in small groups, which can then be combined into a larger action plan.

3.3.1. Variant 1: Local walk

Required Materials: Map for walking route, catalogue of NBS from Chapter 2 (textbook or PowerPoint slides), camera and notebook for documentation

In this variant, a walking route is determined based on the previously identified needs. Depending on time, local, and infrastructural conditions, this can be larger, smaller, on foot, by bike, or with shuttle services. During the walk, hotspots where there are problems with water and sediment retention should be visited, and possible NBS should be discussed on site. The catalogue of NBS can be used as a guide, and the ideas should be recorded in a kind of walk protocol (this can be a map with notes, a protocol, with the help of photos) to be able to summarise this during or after the walk into an action plan. Particular attention should be paid to the possible combination of individual NBS to achieve the best possible effect.

3.3.2. Variant 2: Study map/aerial photo

Required Materials: Maps, aerial photos or hazard zone plans, catalogue of NBS from Chapter 2 (textbook or PowerPoint slides), sticky notes for documentation

In this variant, based on the identified needs, the implementation of possible NBS is worked out using the same maps, aerial photos, hazard zone plans. The catalogue of NBS is available for this, and it can be worked on in small groups or different areas can be worked on by different small groups. Using the maps with notes and sketches or a summarising protocol, the action plan should be presented at the end. Particular attention should be paid to the possible combination of individual NBS to achieve the best possible effect.

3.4. Challenges and Recommendations

Implementing Nature-Based Solutions (NBS) presents unique challenges due to the inherent dynamics and uncertainties of natural systems. Here are some key challenges and recommendations for developing and implementing NBS projects:

Challenges[79]:

- **Uncertainty**: The performance of an NBS is expected to change over time due to the dynamic nature of ecosystems. This uncertainty necessitates continuous monitoring and feedback.
- **Complexity**: NBS projects are more complex than traditional projects due to the multifaceted nature of natural systems and the variety of stakeholders involved. They deal with more uncertainty than traditional projects because the evolution of ecosystems carries inherent uncertainty. Furthermore, NBS form a response to external events that equally evolve under uncertainty. As both the NBS and the external threats will evolve, NBS function in a dynamic and highly complex context.
- **Multidisciplinary Approach**: NBS projects require the application of multidisciplinary approaches, which can be challenging due to differences in language and understanding among different disciplines. Achieving linkage between science, policy, and practice is usually a difficult task. Although this kind of linkage can be facilitated through dialogue, the lack of common language hinders cooperation by causing misunderstandings.
- **Mapping Systems**: Identifying where NBS are allocated is crucial for strategic planning and finding synergies among diverse actors. Mapping systems help urban planners and decision makers identify possible strategic pathways, actions, and NBS interventions. It also helps in overcoming "silos", finding synergies among diverse actors, and suggesting co-financing derived from different sectors.
- **Policy Integration**: NBS planning needs to be embedded in government structures to support sustainable implementation at the local level. The creation of a technical solution may not always have the necessary support in terms of policies, or a new NBS may need change of regulation to become legally feasible.

Recommendations[80]:

- **Aesthetically Appealing NBS**: NBS need to be aesthetically appealing for citizens to appreciate and protect them. They create new green urban commons, spaces that are shared and managed by the community. This fosters a sense of ownership and responsibility among citizens.
- **Co-governance**: NBS projects require a collaborative governance approach involving a wide range of stakeholders. This requires an open and transparent design process. Life-cycle costs need to be considered in order to develop a fair business case. This affects the complexity of the assessment. NBS experiments require and feed into trust between the city and its citizens both for the aim of the experiment and for the experimenting process itself.

[79] Somarakis, G., Stagakis, S., & Chrysoulakis, N. (Eds.). (2019). Thinknature Nature-Based Solutions Handbook. ThinkNature project funded by the EU Horizon 2020 research and innovation programme.

[80] Somarakis, G., Stagakis, S., & Chrysoulakis, N. (Eds.). (2019). Thinknature Nature-Based Solutions Handbook. ThinkNature project funded by the EU Horizon 2020 research and innovation programme;

European Commission, Directorate-General for Research and Innovation, Naumann, S., Burgos Cuevas, N., Davies, C. et al., Harnessing the power of collaboration for nature-based solutions – New ideas and insights for local decision-makers, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2777/954370;

Frantzeskaki, Niki. (2019). Seven lessons for planning nature-based solutions in cities. Environmental Science & Policy. 93. 101-111. 10.1016/j.envsci.2018.12.033.

- **Inclusive Narrative**: An inclusive narrative can bridge knowledge and agendas across different departments of the city. Different fora for co-creating NBS are needed that include and learn from urban social innovation.
- **Sustainable Land Use and Planning**: Innovative approaches for sustainable land use and planning, including the use of NBS, are needed. Spatial policies, such as guidelines, which require the use of NBS and are implemented via master plans, are considered important for NBS development. Policymakers in local governments should be aware of the importance of breaking down silos within their own organisation as part of a wider move towards co-governance with stakeholders and local communities.
- **Stakeholder Engagement**: Stakeholder engagement is crucial for the successful implementation of NBS projects. Stakeholders' means everyone who has a stake in any aspect of your activities - you should think broadly about who will be affected or have an interest. Well-planned and inclusive engagement leads to better outcomes. Start by identifying your stakeholders and then analyse their needs, interests and preferences. You should then map and prioritise your stakeholders to inform the development of your engagement plan. Engagement should be participatory, inclusive and tailored to each stakeholder group.

By addressing these challenges and implementing these recommendations, we can enhance the effectiveness and acceptance of NBS projects, making our communities more resilient to the impacts of extreme weather events.

VII. Annexes - Additional Resources

The chapter provides resources, including manuals, guidelines, and case studies on NBS in water retention and sediment management. These resources can be distributed among the participants of the trainings and/or can be used for the preparation of the training.

1. Guidelines

ThinkNature - Nature-Based Solutions Handbook

The handbook has been developed within the framework of the ThinkNature project. Its primary aim is to compile and promote cutting-edge knowledge on Nature-based Solutions (NBS), providing a comprehensive guide for all relevant stakeholders. Accordingly, each facet of NBS, from project inception to funding and policy formulation, is examined and presented concisely and comprehensively for easy comprehension.

https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5c7061325&appId=PPGMS

EU Commission - Research and innovation

Nature-based solutions and how the Commission defines them, the global context, funding, collaboration and jobs, projects and results, knowledge platforms, latest publications, news and events.

European Commission

https://research-and-innovation.ec.europa.eu/research-area/environment/nature-based-solutions_en

EU Commission - Find your EU funding programme for the environment

This guide provides a detailed description of those 2021-2027 MFF funding programmes and instruments that could support projects that directly or indirectly contribute to the EU's environmental policies and objectives.

https://data.europa.eu/doi/10.2779/768079

EU Commission - Towards an EU research and innovation policy agenda for nature-based solutions & re-naturing cities

Final report of the Horizon 2020 expert group on 'Nature-based solutions and re-naturing cities'

https://data.europa.eu/doi/10.2777/479582

UNaLab URBAN NATURE LABS

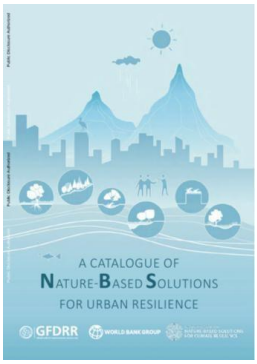
The NBS Technical Handbook focuses mainly on nature-based solutions with large-scale intervention, very intensive management or the creation of new ecosystems.

https://unalab.eu/system/files/2022-11/unalab-nbs-technical-handbook-factsheets2022-11-17.pdf

A Catalogue of Nature-Based Solutions for Urban Resilience

has been developed as a guidance document to support the growing demand for NBS by enabling an initial identification of potential investments in nature-based solutions.

https://hdl.handle.net/10986/36507



2. Case Studies and Platforms

Encourage ongoing knowledge-sharing and collaboration among participants through online platforms or community-based initiatives.

NBS COMICS - NATURE TO SAVE THE WORLD

Nature-based Solutions (NBS) Comics empowers comic creators to combine science and storytelling, re-imagining how people and nature might thrive together.

https://nbscomics.com/

Connecting Nature Enterprise platform

CNEP offers nature-based enterprises a platform where they can connect with their peers, learn about good practices and market trends.

https://naturebasedenterprise.com/

Urban Nature Atlas

is a collection of more than 1000 inspiring nature-based solutions from European cities and beyond.

https://una.city/

Urban Nature Explorers

A simulation game to address sustainability challenges through nature-based solutions.

http://www.urbannatureexplorer.com/

NBS EduDirectory - The resource landscape of NBS Education

This repository provides a comprehensive list of available resources, including guidance, reports, tools, and services developed around education about NBS.

https://nbseduworld.eu/resources

Nature4Cities

is a Nature Based Solutions knowledge diffusion and assessment platform for renaturing cities.

https://www.nature4cities.eu/nature-based-solutions

OPPLA

is the EU Repository of Nature-Based Solutions. It provides a knowledge marketplace, where the latest thinking on natural capital, ecosystem services and nature-based solutions is brought together.

https://oppla.eu/case-study-finder

Nature-based Solutions - Evidence Platform

is an interactive map from the University of Oxford linking nature-based solutions to climate change adaptation outcomes based on a systematic review of the peer-reviewed literature.

https://www.naturebasedsolutionsevidence.info/

NbS Case Study platform

Examples of best practice Nature-based Solutions from around the globe.

https://casestudies.naturebasedsolutionsinitiative.org/

NetworkNature

is a resource for the nature-based solutions community, creating opportunities for local, regional and international cooperation to maximise the impact and spread of nature-based solutions. The project is funded by the European Commission under the Horizon 2020 programme.

https://networknature.eu/

CitiesWithNature

is a unique initiative that recognizes and enhances the value of nature in and around cities across the world.

https://citieswithnature.org/

UrbanByNature

is a facilitated capacity-building programme promoting exchange among cities, researchers, SMEs and NGOs to build bridges with the Nature-Based Solutions communities across Europe, Asia, Latin America, and other interested regions.

https://urbanbynature.eu/

GeoIKP

focuses on NBS as a strategy for hydro-meteorological risk reduction and mitigation (flooding, landslides, coastal erosion, etc.), in both urban and non-urban contexts. The platform enables you to visualise and explore data on NBS for hydro-meteorological risk reduction, use advanced mapping tools, browse NBS case studies, and find relevant policies on the topic.

https://geoikp.operandum-project.eu/

URBAN GreenUP

is an EU-funded project which aims at developing, applying and validating a methodology for Renaturing Urban Plans to mitigate the effects of climate change, improve air quality and water management and increase the sustainability of our cities through innovative nature-based solutions.

https://www.urbangreenup.eu/

Green Communities Guide

is a tool to help communities plan and implement nature-based solutions and strategies to conserve water, protect water quality, preserve agricultural land, and protect critical open spaces and wildlife habitat.

https://greencommunitiesguide.ca/

Susdrain

is a community that provides a range of resources for those involved in delivering sustainable drainage systems (SuDS). SuDS help to manage flood risk and water quality and also improve biodiversity and amenity as well as a host of other benefits to create great places to live, work and play.

https://www.susdrain.org/

European Centre for River Restoration (ECRR)

is considered internationally to be the key network to promote and build capacity for ecological river restoration across Europe, supporting the implementation of the EU Water Framework Directive, Floods Directive and the UN Sustainable Development Goals, the UNECE Water Convention, the Convention on Biodiversity, as well as national policies.

https://www.ecrr.org/

Greenopolis, interactive platform for citizen engagement with NBS

Greenopolis is a digital educational platform with exercises and activities that bring nature into the classroom and bring the pupils out into nature. The digital content is structured into different themes.

https://greenopolis.intugreen.dk/

Schwammstadt

The Sponge City Principle ensures the survival of urban trees in the street environment. It is an innovative system that enables the healthy development of large-crowned trees in paved areas and creates underground retention space for storm water.

https://www.schwammstadt.at/

Öffentliche Freiraumgestaltung

A guide from Southwestern Styria region to demonstrate how and where our communities can take measures that serve both adapting to climate change and promoting biodiversity. The guide provides practical examples for open space design, many of which are implementation examples for community representatives but can be implemented by any individual.

https://www.naturpark-suedsteiermark.at/wp-content/uploads/2021/04/2021-0112-Broschuere-Steiermark-Klimawandelanpassung-1.pdf

Casarico Park

The design for a new neighbourhood in Sorengo (Lugano) is a result of a collaborative effort between architects and landscape architects and responds to the contemporary Swiss requirements in terms of environmental sustainability and liveability of the residents.

https://www.demolfettastrode.com/casaricopark

Dam Removal Europe Award

Dams can be bad for rivers. Award-winning projects show how Europe's fragmented rivers recover when barriers, like dams, are removed, boosting ecosystems and local economies.

https://www.eib.org/en/stories/rivers-biodiversity-dam-removal-award

Stroud Rural Sustainable Drainage Project

The project, which has been running since 2014, aspires 'To create a river catchment where water management is fully integrated into land management practices. Where public bodies, private companies and local communities work together to manage water within the landscape, creating valuable habitat for wildlife and people, and limiting flood risk downstream.'

https://www.youtube.com/watch?v=bUBv8LJ6Wog

https://www.stroud.gov.uk/rsuds