Nature-based Solutions Catalogue

An elaboration of 10 NbS categories in the Dutch situation

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An elaboration of 10 NbS categories in the Dutch situation

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This research was carried out by Wageningen Environmental Research as part of the project ‘Towards a Nature-based Future’ (project no. 5200047633).

Wageningen Environmental Research
Wageningen, April 2024

Cover photo: Shutterstock.com

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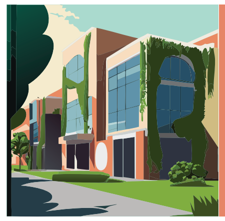
Contents

This catalogue describes ten categories of Nature-based Solutions (NbS) in the Dutch situation. Dividing up NbS into categories helps us to gain a better understanding of the solutions that already exist, how and where they are most effective and which societal challenges they can contribute to. The aim of this catalogue is to provide an overview of NbS that can be used for climate mitigation and adaptation, realizing biodiversity gains and improving human health and the living environment.

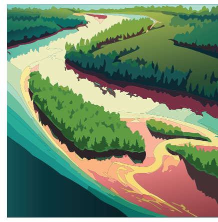
This catalogue, the categories, the societal contributions and the key considerations for implementation have been created and analysed from the Dutch perspective. The catalogue and the results described in it are therefore not applicable to other countries due to the existence of other challenges and spatial characteristics in different international contexts. A context other than the Netherlands can lead to other categories of NbS, societal contributions and key considerations.

Dynamic Nature Management

Natural Coastal Defences



Biobased Building



Restoration of Streams and Rivers

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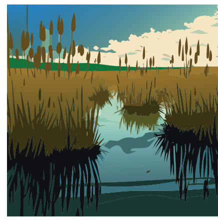
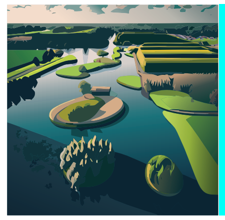
Rewetting

Restoration of Estuaries



Natural Water Purification

Green-blue Infrastructure



Freshwater Storage

Introduction

There are many different possibilities for using nature to tackle societal challenges. These are known as Nature-based Solutions (NbS). Think of meandering streams that retain water for a longer period, green cities that provide cooling or oyster reefs that act as natural coastal defences – there are countless examples. This catalogue is primarily intended to help policymakers to gain a better understanding of the diversity and potential of NbS, but it can also be used to inform researchers and other interested parties.

Nature-based Solutions are receiving a lot of attention from researchers, policymakers and practitioners alike. Several sectors work with the same principle, but with different terminology. Terms described here include 'nature inclusive', 'building with nature' and 'natural measures' designed to improve 'ecosystem services'. The aim of all interventions is more or less the same, namely to use natural solutions for societal challenges such as heat stress, soil subsidence and water purification while simultaneously restoring and boosting biodiversity. The use of NbS provides mutual benefits for both humans and nature. These often involve different stakeholders, many of wh om are influenced by them. Which stakeholders these are varies depending on the NbS, the geographical location , the challenge and the post-implementation impact.

> *"Nature-based Solutions are actions to protect, sustainably manage, and restore natural and modified ecosystems in ways that address societal challenges effectively and adaptively, to provide both human well-being and biodiversity benefits. They are underpinned by benefits that flow from healthy ecosystems and target major challenges like climate change, disaster risk reduction, food and water security, health and are critical to economic development."*
>
> *Cohen-Shacham, E., Walters, G., Janzen, C., Maginnis, S., 2016. Nature-based solutions to address global societal challenges*. IUCN Gland Switz. 97, 2016–2036.

In 2020, researchers from Wageningen University & Research presented a vision of what the Netherlands could look like in the year 2120. This vision and the associated solutions formed the starting point for the categories of NbS in this catalogue. Clustering NbS into categories helps to make the variety of different individual measures easier to comprehend. The categorisation was based on the challenges that NbS can address, such as the risk of flooding, and the natural processes exacerbated by these solutions, such as sedimentation. This resulted in ten categories in which the active use of nature, the challenges and natural processes take centre stage, allowing us to demonstrate that natural processes can help us in many areas of the challenges we are facing, regardless of the precise locations where the issues arise.

For each of the ten categories of Nature-based Solutions, this catalogue presents the challenges for which they can be used and the measures they can include, and provides some inspiring illustrative examples. There are already many examples in the Netherlands where nature is being restored or developed with NbS being applied on various scales. We are therefore actively working towards a nature-based future. The societal contributions and key considerations for implementing the NbS categories are also described.

Dynamic Nature Management

Management and design measures aimed at stimulating and enhancing natural processes and dynamics.

Introduction and challenges

In the Netherlands, large-scale dynamic nature has disappeared in many places due to cultivation of the land and the creation of defences against natural processes. One such example is the canalization of streams and rivers, which eliminates drainage and flooding dynamics but also closes off estuaries, causing tidal dynamics to disappear.[1]

Landscape policy designed to achieve nature goals is detirmined to a large extent by target species. The deliberate and selective championing of certain animal and plant species limits local dynamics, because strict frameworks are put in place when reintroducing a specific species to an area, as is the case with the management of ground-nesting bird areas or hay meadows.[2] In dynamic nature management, a fixed end goal with defined target species is not a central starting point. Instead, the focus is on nature management that can keep pace with natural processes, even if they are transformed as a result of climate change.[2]

Artist's impression of Dynamic Nature Management with rejuvenated vegetation and drifting sands.

Societal contributions

Climate adaptation and mitigation: Resilient, dynamic nature is better able to withstand the various threats posed by a changing climate, such as fragmentation and the arrival of invasive species caused by the northward migration as a result of climate change.[3] [4] Developing more dynamic nature can also provide additional water storage, thus helping to make the landscape more resilient in times of drought. This is because dynamic nature helps to prevent soil subsidence and can improve water retention in high sandy soils. [2] [5]

Biodiversity: Dynamic nature management can help to improve and diversify habitats for biodiversity by creating different succession stages which are preserved through natural dynamics.[4] For example, grazing by large herbivores has a positive effect on the diversity of species in grasslands, which become wilder than without grazing.[2] By giving space to natural processes through dynamic nature management, ecosystem services are andhanced with greater biodiversity. Foreshore dynamics provide space fore geomorphological processes and therefore natural vegetation and biodiversity along the coast.[6]

Health: Natural areas, including dynamically managed areas, are often open to visitors for recreation and education.[4] They help to encourage exercise and relaxation, thereby benefiting people's physical and mental health. These positive health effects are greater in accessible areas of high ecological value.[7] In addition, the risk of pests is lower in a more biodiverse environment, and dynamic nature management has a positive impact on water safety and water quality, resulting in fewer physical and mental health risks. [8] [9]

Key considerations for implementation

Local environment: Dynamic nature management is primarily relevant to natural areas. These can be in any conceivable types of landscape: in river areas, for example, where natural dynamics in runoff and meander dynamics are reintroduced; along the coast, where dunes are rewilded; and forests managed in a way that creates more space for native species. Depending on where they are located, these natural areas can provide a host of ecosystems services for the surrounding regions, such as water purification, freshwater storage and recreation.[4]

Scale: Interventions on a large scale – at the landscape level – often deliver the best outcomes because they enable hydrological and landscape-forming processes to be applied to create genuine dynamics.[2] [4] However, this can also be done on a smaller scale, such as introducing grazing in a small area, or urban nature in more densely populated areas to enable more natural processes to come about.[4]

Costs

Land: Costs are limited, as the locations where dynamic nature management takes place are often already natural areas with some form of management. It may also be possible to exchange land with farmers, thus creating larger areas for nature, for example.[4]

Realisation: Interventions may be needed, such as excavating dune areas[10], intervening in the vegetation or removing obstacles in a river area[11], but also enclosing an area for grazing.[12]

Maintenance and management: Interventions and management may be needed at regular intervals. After all, dynamics can diminish over time, such as when notches in dunes become blocked with drifting sand.[4]

Examples

Introduction of large herbivores to create natural variation in landscapes, such as in de Kleine Willemswaard

Dynamic floodplain management in the Klompenwaard for flood protection and biodiversity [11]

Kerf bij Schoorl for shifting sands and letting nature take its course [4]

Biobased Building

Using biobased, local and renewable materials for construction and create the required product chains.

Introduction and challenges

The construction sector generates substantial levels of greenhouse gas emissions. The manufacturing of concrete, cement and steel, for example, is a highly energy-intensive process which relies heavily on fossil raw materials that emit huge amounts of CO_2.[13]

On a global scale, emissions from construction activities make up 21% of total emissions, of which 18% comes from the use of cement and steel.[14] In order to make the construction sector more sustainable, it is therefore necessary both to build with raw materials that are less polluting and to reduce emissions from the buildings themselves, for example by improving the insulation of existing buildings.[13]

Biobased materials consist of natural biotic raw materials, such as wood, flax, cattail (Typha) or hemp. These can be used for construction and insulation materials. Bioplastics, fungi and bacteria cultivated in an ecologically responsible manner are also examples of sustainable biobased applications. Building with biobased materials offers a circular solution because they are renewable. Depending on local conditions, biobased materials can be cultivated locally. This reduces transport distances and has the additional effect of reducing global dependence on fossil products. Besides being used in construction, most biobased materials also act as a form of carbon sink.[15] [16]

Societal contributions

There are multiple opportunities for biobased building to respond to various societal challenges. For example, biobased building could help to accelerate housebuilding, which is currently being held back by nitrogen legislation in the Netherlands, and to develop circular methods of building that involve lower emissions. If demand and supply of materials are properly matched, biobased building also offers the opportunity to tackle the scarcity of raw materials and security of supply.

Climate adaptation and mitigation: Biobased building can play a role in CO_2 reduction and storage. Replacing steel or concrete with wood saves 1.5 tonnes of CO_2 per tonne of product.[16] Furthermore, growing wood and hemp is an extremely effective method of storing CO_2.[17] [18] [19]

Biodiversity: If implemented correctly in a way that is compatible with the local landscape, biobased building can boost sustainable forest management in Europe and other parts of the world.[20] [21] Ecological gains can also be made in terms of farm land use: planting deep-rooting fibre crops in strategic locations can help to reduce runoff, for example.[22]

Health: Biobased materials in the built environment retain heat for shorter periods of time than abiotic materials such as stone or concrete and therefore create a more pleasant microclimate in the urban setting, both indoors and outdoors. This contributes to reducing heat stress in towns and cities.[23] It also impacts positively on the health of residents, users and people in the vicinity of biobased buildings. Because biobased materials often have porous or fibrous surfaces, they impact positively on acoustics in towns and cities.[24] [25]

Artist's impression of Biobased Building, in which natural raw materials have been used and a green living environment has been achieved.

Key considerations for implementation

Local environment: Producing biobased materials can potentially have trade-offs i n different areas (peat grasslands, forest areas) with other land use functions such as food production. At present, the lack of proper coordination between demand and supply results in weak links in the production chain. In addition, with limited space for growing crops in the Netherlands, there is not yet a reliable, year-round supply of biobased raw materials.

Scale: Biobased materials can be grown anywhere, and biobased building can be used at any scale: at the household, urban or landscape level. There is certainly plenty of wood in Europe: in Finland, enough wood to build a new house grows every 14 seconds, and a third of Germany is covered with forest.[17] However, it is a challenge to correctly match the demand and supply of biobased materials and to distribute them regionally, yet as locally as possible.[20]

Costs: Biobased materials have the potential to make a meaningful return from a waste stream as a cost item, as is the case with plant clippings for biocomposites or insulation. Costs can be saved because fewer transport movements are needed and components can be delivered prefabricated. At the moment, however, there is still a lack of knowledge about this among buyers, making it even cheaper to build with conventional materials that are usually produced in non-renewable processes. On the one hand, the switch to biobased crops is still too risky due to the uncertainty or potential suppliers.

On the other hand, buyers are not yet aware of the range of biobased products available, and the specifications of these products are unclear. As a result, the risks are poorly understood and there is little professional knowledge available concerning the use and maintenance of these products.

Land: To ensure a reliable supply of biobased materials, the cultivation of these building materials will bring about structural changes in land use and in the role of the farmer.

Realisation: An increase in biobased building will provide opportunities for farmers to switch to a different revenue model. Farmers will be able to earn money from growing fibres. Farmers can be given certainty in terms of this income stream if this prospect is included in the National Rural Area Programme (NPLG) plans (e.g. the Nitrogen Fund).[22]

Maintenance and management: Transitioning to biobased building will once again shine the spotlight on a different kind of craftsmanship. Maintenance of the buildings themselves takes a different form from that of conventional buildings, and knowledge will again once more become more specialised, depending on the origin and properties of the building material.

Examples

The use of wood as a building material, as highlighted at Houtbouw

Gebouw Haut is the tallest hybrid wood building in the Netherlands and one of the largest in the world

The 14,000 m² Dalston Works London houses apartments, office space and restaurants

Nature-positive Food Production

Food production that is resilient to natural dynamics in which natural processes are used to improve soil functions and biodiversity.

Introduction and challenges

Due to intensification and mechanisation, conventional land-based agriculture has become out of balance with its surroundings, with the result that ever more artificial measures are needed to maintain the intensive system, often at the expense of nature and the environment. Common problems include acidification and runoff from overfertilisation, soil erosion, drought (exacerbated by climate change) and biodiversity loss.

Nature-positive food production, also known as nature-inclusive agriculture, is agriculture that uses, enriches and conserves nature[26]:

1) Using nature: by making use of natural processes such as pollination and natural pest control.

2) Enriching nature: if you want to be able to use natural processes, you must integrate and promote species and soil biodiversity on your farm.

3) Conserving nature: avoiding focusing on maximising yields, which involves the use of many external and artificial inputs that harm the natural system, such as the use of artificial fertilisers instead of animal manure.

By nature-positive food production we mean an agricultural practice that makes sustainable and responsible use of natural resources such as soil and water. Broadly speaking, this is about agriculture working together with nature rather than at each other's expense. This may also lead to farmers choosing alternative crops that are better suited to the soil, water and natural systems and the changing conditions in them.

Societal contributions

Climate adaptation and mitigation: Nature-positive food production on land helps improve the resilience of the soil. A resilient soil can better cope with extreme weather conditions caused by climate change. This is partly due to the improved soil structure and increased carbon storage that provide better water regulation.[27] At the same time, carbon sequestration helps reduce CO_2 in the air.[28]

Biodiversity: All measures a farmer applies in terms of nature positive food production are geared towards contributing to biodiversity and its restoration. These include agricultural nature-management, but also the switch to natural pest control and reducing the use of fertilizers and antibiotics. Nature-friendly food production restores, preserves and enriches biodiversity by reducing environmental pressure factors and giving nature more space.[29] Strengthening biodiversity also has benefits for agriculture, such as encouraging pollination and natural pest control.[30][31]

Health: Nature-positive food production reduces health risks emanating from pesticide use and particulate matter in conventional agriculture.[32] The recreational value of rural areas will also increase as nature values improve.

Artist's impression of Nature-positive Food Production, in which multiple crops are grown and landscape elements are present.

Key considerations for implementation

Local environment: Due to the diversity of measures involved in nature-positive food production, it is applicable in and relevant to all landscape types. Whereas drought and leaching are common problems on higher sandy soils, salinisation poses a problem on the coast of the Netherlands. Nature-positive food production offers solutions for both situations. The nature of these solutions is specific to the landscape concerned (for example, the use of freshwater lenses in the northern clay polders.

Scale: Nature-positive food production lends itself to being used on all scales, from plot to landscape level. The larger the scale on which it is applied, the more effective it is in achieving climate and biodiversity goals. It can improve biodiversity on the farm, but this can increase dramatically if the right green-blue connections to the surrounding landscape are in place (see also 'Green-blue Infrastructure').

Costs

Land: Measures for nature-positive food production can take up space, such as field margins for planting with wild flowers, which reduces the area of land in production.

Realisation: In general, conversion to nature-positive agriculture requires substantial investment in of the form of potentially lower yield, which will pay off in the long term by providing biodiversity and ecosystem services. This is because the natural system on agricultural land needs time to develop before its 'fruits' can be reaped. The farmer therefore needs to be able to bridge this period financially in other ways. Moreover, there is an important role for the market in reimbursing the extra cost of producing nature-positive products.

Maintenance and management: Nature-positive food production requires a fundamentally different approach to farming methods, which is still evolving. This means that the costs of 'maintenance' such as weed control and the use of organic manure, for example, are currently higher due to higher labour costs and the greater scarcity of manure, respectively.[33] The expectation is that innovations in automation will eventually bring these costs down again.

Examples

A 20-hectare production food forest in Schijndel

Organic strip cultivation in Goeree-Overflakkee

A forest farm with nuts and berries at Janmiekeshoeve

Extensification and grazing of young stock on salt marshes in the project 'Farming with nature' on the island of Schiermonnikoog

Restoration of Estuaries

Redesigning river estuaries to provide more room for natural gradients (such as freshwater-saltwater transitions), tidal dynamics and sedimentation processes.

Introduction and challenges

In a natural landscape, every estuary has a gradual freshwater-saltwater transition (gradient). In estuaries, tidal ebb and flow creates a varying pattern of gullies, creeks, sandbanks and silt deposits. This dynamism keeps this natural system in balance. This means that there is sufficient sediment and the tidal dynamics correspond to the dimensions of the basin.[34] Human intervention such as land reclamation, the construction of infrastructure and channel narrowing has disrupted this balance. For example, the tidal range in the Eastern Scheldt is unnaturally low and there currently is no tidal range at all in Grevelingen. In areas where tidal dynamics have decreased, marshes and mud flats are disappearing as a result of sand depletion, when more sediment is removed via the channels than is supplied and deposited on the salt marshes and mud flats.[35] The opposite is true in other areas such as the Eems-Dollard estuary, where the increase in tidal dynamics in combination with anthropogenic factors is preventing silt deposition and causing turbidity.

Both situations cause problems with flood safety and water quality, which also impacts ecological quality in some areas. The restoration of estuaries aims to reintroduce natural tidal dynamics, leading to the sustainable development of estuaries.

Societal contributions

Climate adaptation and mitigation: The restoration of estuaries helps to boost carbon sequestration on salt marshes by preventing the erosion of marsh margins.[36] In the Netherlands, salt marshes are the most important storage sites for blue carbon.[37] Creating more salt marshes, preventing erosion or making management more sustainable enables this ecosystem to retain carbon or even increase the amount of carbon it stores.[38] Salt marshes also act as a natural buffer against wave action, reducing the pressure on dykes. However, factors that benefit carbon storage are not necessarily beneficial for biodiversity on the salt marshes. The height increase boosts carbon sequestration but also creates a less dynamic situation dominated by medium-height salt marsh vegetation.[38]

Biodiversity: Restoration of freshwater-saltwater transitions opens the gateway for fish such as salmon and sea trout to the freshwater in which they reproduce.[35] In addition, freshwater-saltwater transitions are a breeding ground for many commercial and other fish species from the North Sea and elsewhere and have a significant impact on the productivity of the system. The ecologically variable dynamics play an important role as a foraging area for migratory birds. Restoration of balance in sedimentation processes improves the habitat as a breeding ground for meadow birds and waders and an overwintering area for migratory birds.[34] In general, restoration of tidal dynamics boosts the population of marine invertebrates by ensuring a continuous flow of water, and and replenishing the supply of nutrients.[39]

Health: Due to climate change, sea levels are set to rise in the coming years. This NbS helps to improve flood safety by increasing the inflow of sedimentation, allowing mud flats and salt marshes to continue to grow in line with the rise in sea levels and preserving the stability of dykes.[36] This contributes to people's sense of safety and mental health.

Artist's impression of Restoration of Estuaries, in sedimentation processes to be restored which salmon can migrate to their spawning grounds and waders can breed.

Key considerations for implementation

Local environment: This NbS is relevant everywhere in the Netherlands where rivers originally discharged into the sea. The only two estuaries still functioning are the Eastern and Western Scheldt and the Eems-Dollard. Potential for applying this NbS can also be found in Haringvliet and Grevelingen. Due to the important role it plays in river drainage, the Haringvliet estuary is an area where a combination of measures is needed.

Scale: The scale of application of this NbS can vary from making a breach, inlet in existing structures or dykes (restoring the connection to the sea) or to the construction of double dyke systems with natural and hard coastal transitions, and applying sand nourishments. The latter involves building a body of sand off the coast several kilometres long to counteract sand depletion and redesigning the entire area to achieve a 'natural' coastal transition (see "Natuurlijke kustverdediging"). An important underlying principle for this is that it must be able to develop along with the rate of impact of climate change.
Costs

Land: When applied to situations on the seaward side of dykes, this NbS does not require any additional land; however, it does impact land use functions on that side of the dyke, such as cultivation and recreation. In the case of solutions on the landward side, such as double dykes, these functions are adapted (e.g. to saline cultivation or aquaculture). It is also possible that restoring tidal dynamics may cause polders to flood more frequently, for example, requiring appropriate agreements to be reached with landowners and users.

The potential additional salinisation in these areas will result in functions being exchanged, so the impact on local land use functions must be taken into consideration.

Realisation: For the restoration of estuaries, dyke strengthening tasks must also be included. These can often be performed at the same time.[40] This NbS can also be taken into account when undertaking dyke strengthening, as a result of which the extent of the strengthening required may vary. Take the example of wave action against the dyke: this is reduced by the foreshore, meaning that the dyke requires less frequent maintenance, which can be more cost-effective.

Maintenance and management: The natural dynamics in estuaries can never be fully restored on account of flood risk protection. Maintenance of this NbS will therefore always be needed. This includes periodic rejuvenation of ageing salt marshes, relocation of sediment and periodic sand suppletion.[34] In addition, nature management and dyke management and maintenance will continue to be needed in order to meet flood safety standards.

Examples

Nature development as an evolving form of coastal protection, as in the Oesterdam safety buffer

Research into creation of salt marshes in the Peazemerlannen nature reserve as a means of carbon storage [38]

Restoring the international crossroads for fish and birds during their migration routes by by slightly opening the Haringvliet sluices

Waterdunen in West-Zeeland Flanders: Construction of a tidal culvert, enabling tidal nature and sedimentation processes to be restored

Green-blue Infrastructure

Restoration and creation of interconnecting green-blue landscape elements (both in urban and rural areas) for the benefit of landscape characteristics, natural pest control, crop pollination, corridors and habitat for biodiversity, improving water and air quality, cooling and water buffering.

Introduction and challenges

If properly constructed and managed, green-blue infrastructure (GBI) provides important services in both urban and rural areas. Rural areas face major challenges in terms of nature, water, climate and agriculture. These challenges are closely intertwined and take up a lot of space in these areas. GBI contributes to integrated solutions by providing ecosystem services. In urban areas, GBI plays a key role in creating a healthy living environment and mitigating the effects of climate change. Managed by farmers, public authorities and private individuals, GBI can be seen as a network of natural elements connecting farms with the landscape.[41] Green-blue infrastructure therefore provides a valuable common basis for tackling societal challenges in an integrated way.[42]

Artist's impression of GBI, in which an ecoduct and green verges create an attractive habitat for flora and fauna.

Societal contributions

Climate adaptation and mitigation: GBI provides ecosystem services that contribute to climate mitigation, such as sequestering CO_2 in the soil and in wood. In addition, GBI plays a role in climate adaptation. Greening brings about cooling by slowing down urban warming and providing shade as well as improving water regulation.[43]

Biodiversity: Research shows that GBI is the habitat for the bulk of biodiversity in rural areas.[44] Therefore, focusing on the quantity and quality of GBI helps improve biodiversity and ecological connectivity. Towns and cities are often referred to as having 'islands' of biodiversity, such as parks and wooded areas that often serve as refuges for (endangered) species from rural areas.[45] GBI helps to connect these areas, which benefits biodiversity.

Health: GBI directly contributes to reducing heat stress in urban areas. It invites people to cycle more often than drive and improves air quality, quality of life, noise nuisance and road safety. Moreover, green zones have a stress-reducing effect on people. In towns and cities, it is mainly people from low-income and migrant backgrounds who live in neighbourhoods with very little green space. They are the first to experience the effects of urban heat stress and are least able to bear the financial consequences (e.g. medical expenses). Targeted greening can therefore play a role in achieving more inclusive health in the urban setting.[46]
In rural areas, GBI indirectly contributes to mitigating health risks by allowing farmers to cut down on pesticide use and reducing runoff, thereby helping to reduce product contamination and pollution of surface water and groundwater. However, rewetting an area in combination with climate change can lead to an increase in insects such as mosquitoes, which can increase the risk of vector-borne diseases.[47] [48]

Key considerations for implementation

Local environment: Green-blue infrastructure can be applied in all landscape types. The strength of this NbS lies in its function of connecting a variety of green-blue landscape elements in different landscape types.[49] To be able to use GBI as an NbS, it is essential to have variation in structure, crops and floral diversity. This might entail a combination of woody and grassy elements adjacent to a plot with strip cultivation, for example.[41]

Scale: GBI can be applied from the plot and street level to the landscape level. However, in order for GBI to be used as an NbS for societal challenges, a minimum surface area of 10-15% is needed in the landscape (rural area).[41] Another prerequisite is that the GBI must be distributed widely and densely across the landscape, seamlessly adjoining agricultural fields with nature-positive food production, for example. The same principle applies in urban areas.

Costs

Land: In rural areas, the construction of GBI mainly takes up space on agricultural land. In practice, this often boils down to landowners voluntarily managing agricultural land as GBI. Grants are sometimes available for this. GBI also includes verges along infrastructure which are often owned or managed by public authorities. In urban areas, the construction of GBI predominantly involves depaving, both in public spaces and in residents' gardens.

Realisation: In rural areas, landowners can obtain construction and management allowances for GBI. The 'Aanvalsplan Landschap' (Landscape Attack Plan) has calculated that building 10% of GBI in rural areas would cost roughly €5.3 billion.[49] No such concrete numbers are available for urban areas. Because green space does not deliver direct benefits and the pressure on land is high, it still frequently loses in competition with use functions that do deliver direct monetary benefits.[50] There are various small-scale initiatives in urban areas through which citizens can receive compensation for replacing paving with plants or creating green areas in public spaces.[51]

Maintenance and management: In rural areas, landowners can obtain construction and management allowances for GBI. The 'Aanvalsplan Landschap' has calculated that managing 10% of GBI in rural areas would cost roughly €257 million per year (calculated over a 30-year period).[49] In urban areas, green space management is a costly business. By providing ecosystem services, GBI can reduce these costs. They could, for example, be shared between municipal departments on account of the range of benefits they deliver, and consideration could be given to natural forms of management that are less costly.[52]

Examples

Roll-out of a Green-blue area-based approach in Aadal Noord to make the area climate resilient

Development of a targeted approach focusing on cohesion between ANLb measures and eco-measures on an area level

Study looking into quantifying the natural capital of green-blue infrastructure in Rotterdam

The whole of the Netherlands is lifting paving for a more climate resilient Netherlands: which municipality is lifting the most paving?

Natural Coastal Defences

Aim for flexible, adaptive coastal defences by utilising, supporting and stimulating natural processes such as erosion and sedimentation, which simultaneously leads to other benefits such as ecosystem restoration and recreation.

Introduction and challenges

Faced with sea level rises and stronger storms caused by climate change[53], it is essential that the Dutch coast provides effective protection for the hinterland. To meet stringent flood safety standards, the decision is often made to implement grey technical solutions such as dykes and flood defense systems like the Deltawerken in the Netherlands. Unlike these types of engineering solutions, natural coastal defenses can not only provide protection but also adapt as conditions change, such as further rises in sea levels or future uncertainties around storm magnitudes and frequencies, by facilitating natural, dynamic processes such as sedimentation and erosion.[54] This allows the coastline to evolve in tandem with rising sea levels and create a more natural coastal landscape with a greater diversity of habitats, flora and fauna.

Besides creating space for recreation, natural coastal defences offer a good opportunity for the development of biodiverse ecosystems, especially when managed more adaptively. These types of areas with multiple functions are also known as water safety landscapes.[55]

Societal contributions

Climate adaptation and mitigation: Flexible and adaptive coastal flood protection helps to adapt to climate change. Natural coastal defence complexes will often grow in tandem with sea level rises by creating space for processes such as sedimentation (for example, a salt marsh growing during tidal flooding and aeolian sediment transportation in dunes. [56] [57]

Biodiversity: Natural coastal defences allow ecosystems such as dunes and beaches to be restored with a more natural coastal gradient by facilitating natural processes such as erosion, sedimentation and drifting. They also often form hotspots for biodiversity (see also 'Dynamic Nature Management').[58]

Health: Compliance with flood safety standards can often prevent casualties and damage. This not only limits potential acute consequences such as drowning, infections and physical damage but also long-term consequences such as emotional trauma.[59] In addition, new areas in which natural coastal defences are implemented often provide space for recreation.[60, 61] Various studies show that access to the coast helps improve mental health by reducing stress, anxiety and depression. Moreover, this has been shown to stimulate physical activity, thereby improving physical health and vitality in general.[62] [63] The magnitude of these effects is greater with a natural, healthy coast.

Artist's impression of Natural Coastal Defences, in which natural processes are given space in a salt marsh landscape.

Key considerations for implementation

Local environment: This NbS is relevant in coastal areas. Natural coastal defences are already present in various places and forms such as dunes, salt marshes, sandbars and mud flats. However, these are under pressure from anthropogenic and climatic influences. In other locations, they are completely absent or require strengthening. The principles of natural coastal defences also apply along the IJssel- and Markermeer coasts.

Scale: These are often large landscape-level interventions, partly because small-scale interventions can shift the problem to a location further down the coast. Due to the extensive scale, key problems and weak links are tackled and remedied in one go.

Costs

Land: Coastal activities (such as a recreational beach) may have to give way at least temporarily to the construction of a natural coastal defence complex, such as a sand dyke. However, new land is also often created after the intervention is completed, providing new space for both people and nature.

Realisation: These are sizeable and costly projects, such as large-scale sand suppletion or creation of new dune areas. However, the intention is that the projects will be more robust and will require less maintenance.

Maintenance and management: Monitoring and management of the areas, new or ongoing sand suppletion, but also supervision of recreational areas.[61] Active management of natural areas may be required, as the solution may involve water management works that are subject to mandatory maintenance.[64] This depends in part on the maintenance standards formulated for the NbS. The standard may include ongoing monitoring, for example; the results of the monitoring will then inform when maintenance is next needed.

Examples

Restoration of sandy foreshore for coastal defences and nature development in the Hondsbossche Dunes

The internationally iconic project 'Sand Motor' because of large-scale sand suppletion

Research into ecological and morphological salt marsh development in Salt Marsh Development Marconi Delfzijl

Restoration of Streams and Rivers

Interventions that slow down water discharge, increase the storage and infiltration capacity of waterways as a method of combining water safety and nature development.

Introduction and challenges

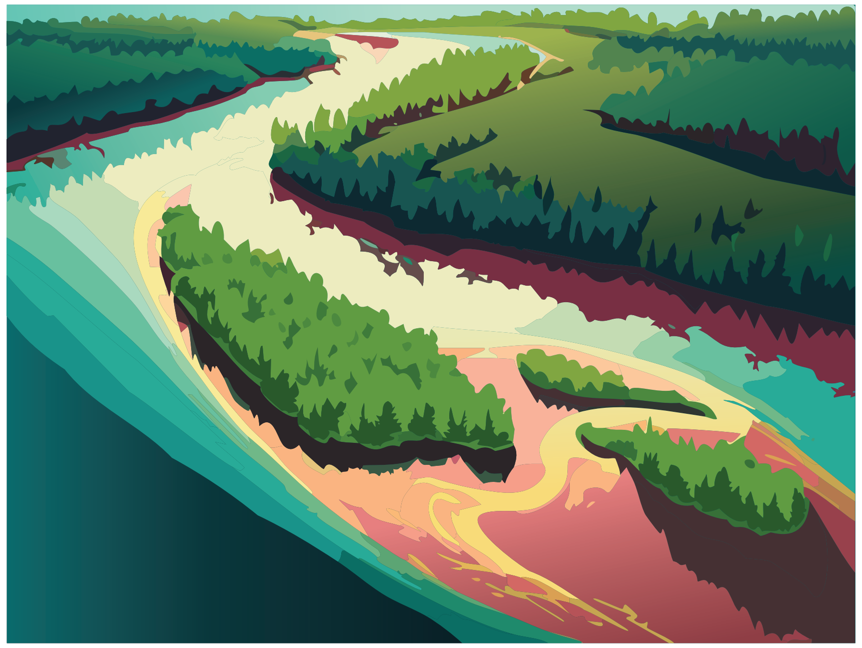
As a delta, the Netherlands is vulnerable to flooding. Climate change is increasing peak discharges due to more frequent periods of heavy rainfall and melting of snow and ice in the catchment.[65] More long, dry periods are expected, resulting in low river discharge levels. As a consequence, streams are at increased risk of stagnating or drying out. To deal with this effectively, it is important to slow down the discharge rate from catchments and store the water to ensure gradual discharge. This can be done by giving streams, rivers and their valleys a [66] more natural form, for example by re-meandering straightened sections, extending floodplains to give water more space during flood events, and removing drainage elements so that more water is retained in the tributaries of the water system. Creating space for streams and rivers combines well with wetland development and freshwater buffering.[66] The quality of nature improves because the naturaldynamics associated with flooding provide more variation and dynamism in the landscape.

Societal contributions

Climate adaptation and mitigation: Space to store water during peak discharges helps to prevent flooding downstream. Creating more space for river water prevents riverbed erosion (incision) and therefore helps to prevent stream or river-supported nature from drying up. In addition, improved buffering and infiltration of water (aquifer recharging) play a positive role in improving the drought resilience of the landscape.

Biodiversity: Space for dynamic nature, which allows for variation in environmental conditions (reversing vegetation succession to create pioneer conditions, releasing riverbed substrate used by fish to spawn), thus delivering more biodiversity (see also 'Dynamic Nature Management').

Health: Redesigning streams and rivers creates more space for recreation and experiencing nature, with all the benefits these bring. Moreover, it reduces the risk of flooding and therefore casualties and physical damage while simultaneously benefiting the supply of freshwater.



Artist's impression of Redesigning Streams and Rivers, in which sedimentation and erosion create gradients in the landscape.

Key considerations for implementation

Local environment: Measures can be implemented effectively in river areas, stream valleys on higher sandy soils and in hilly terrain.[67] They can be used in natural as well as agricultural and urban areas.

Scale: To ensure maximum effectiveness, measures should be taken at the landscape level. To achieve this, the entire catchment should be considered, since upstream interventions have an effect downstream. Because multiple obstacles can occur simultaneously in catchments (e.g. hydrological and morphological disruption), measures should be deployed in an integrated way. As of yet, this very rarely happens in practice.

Costs

Land: Creating space for streams and rivers affects the current land uses. Depending on the local context, land in the stream or river valley can be acquired, or landowners can be compensated for water functions, for example.

Realisation: The investments required for this NbS vary for activities such as re-meandering, modifying a stream profile by working with sand suppletion, introducing dead wood and lowering summer embankments.[66]

Maintenance and management: If there is sufficient space available, maintenance could be reduced. Sometimes it is necessary to mow riparian vegetation to facilitate the flow of streams. Currently, floodplains must be kept clear of woodland cover as this can reduce the flow capacity of the river.[68]

Protection against flooding is not accomplished after a particular length of time because river discharges can change over time. Water levels and the hydromorphological and ecological effects of interventions (erosion, sedimentation, nature development) must be monitored. An adaptive approach is preferred, in which additional interventions are carried out when necessary, but with priority being given to a one-off intervention, after which further development is shaped by natural processes (building with nature).

Examples

Room for the River – Various projects to reduce the risk of flooding by giving rivers more space

Stream restoration in the Leuvenumse beek to absorb precipitation peaks and for nature development

Re-meandering of streams in Drenthe to limit flooding and improve ecological water quality

Rewetting

Raising groundwater levels to reduce subsidence, greenhouse gas emissions and salinisation without the need for a substantial increase in the supply of freshwater.

Introduction and challenges

The low-lying areas of the Netherlands (the west of the country, but also parts of Overijssel, Friesland and Groningen) were originally peatlands. The accumulation of plant debris combined with a high water table formed fens there. In the higher parts of the Netherlands (such as Drenthe, Gelderland, Brabant and Limburg), raised bogs formed under the influence of nutrient-poor, acidic rainwater. Many peatlands were drained for agriculture and peat extraction by creating ditches. Drainage leads to peat oxidation, which in turn causes subsidence and gradual rewetting of the soils. In response, water levels are further lowered to keep the land suitable for agriculture, creating a self-perpetuating effect.[69] This ongoing subsidence necessitates major investments in the water system and causes extensive damage to housing and infrastructure and CO_2 emissions. Rewetting peat grassland counteracts salt penetration in a natural way and reduces peat oxidation and subsidence.

Artist's impression of Rewetting, in which the water level in peat grasslands in agricultural use has been raised to just below ground level.

Societal contributions

Climate adaptation and mitigation: Extensive research is currently being done into the impact of rewetting on the climate. On the one hand, rewetting prevents peat oxidation, thereby reducing CO_2 emissions. By applying a package of measures in peat grassland areas (passive rewetting, underwater drainage and land use), it is possible to achieve a 25 percent reduction compared to the current situation.[70] On the other hand, rewetting can lead to methane emissions. Since methane is 30 times more potent than CO_2, investigations are ongoing into the key processes and the best way to influence them so as to minimise peat degradation and methane emissions.[71] In addition, calculations show that in drier periods, large-scale rewetting can lead to shortages of freshwater.[72] The question is therefore to what extent rewetting is desirable and possible. Rewetting can counteract salinisation processes in coastal areas.

Biodiversity: The extent to which rewetting contributes to biodiversity depends to a large degree on site-specific conditions such as nutrient levels in the ecosystem. As we have a lot of agricultural land in polders in the Netherlands, rewetting these soils would mainly create nutrient-rich (eutrophic) wetlands.[73] Marsh-breeding species such as the bittern or sedge warbler thrive.[74] More wetland conditions create ideal foraging grounds for waders such as the lapwing and redshank.[75] In general, rewetting helps increase insect populations, which is good for biodiversity in general.

Health: Rewetting measures can entail greater health risks for animals and humans. The dwarf pond snail, for example, thrives in damp peat grassland conditions. This snail can have an adverse affect on the health and productivity of dairy cattle, which is detrimental to animal welfare and farmers' incomes. Lactating cows cannot be treated, and preventive measures are as yet limited.[76] In addition, stinging insects such as mosquitoes and midges thrive in stagnant, nutrient-rich water, thereby increasing the risk of vector-borne diseases and causing nuisance.[77]

Implementing landscaping and management measures such as keeping high-growing vegetation in check can limit the spread towards built-up areas.

Key considerations for implementation

Local environment: Rewetting is mainly relevant in areas in which peat is present. Besides peat grasslands, peat can also be present on the high sandy soils in stream valleys. Just as in coastal areas, rewetting is an important measure for counteracting salinisation in these locations too. 'Freshwater storage' in a general sense is discussed in a separate NbS category.

Scale: Rewetting measures such as gulley infiltration and pump-controlled underwater drains can be taken at the individual plot level. Underwater drainage requires additional water to be supplied during dry periods. Calculations show that the large-scale application of this measure results in a shortage of freshwater in the surface water system in dry periods.[72] Hence, a landscape-scale approach is needed to retain freshwater in the water system (see also 'Freshwater Storage'). Combinations of measures that reinforce each other are also possible, such as combining a passive increase in the water level and underwater drainage.[72]

Costs

Land: Depending on the nature of the rewetting measure, there may or may not be land acquisition costs involved. Much of the land in peat grassland areas is owned by farmers or nature organisations or is urban area. Research shows that underwater drainage does not result in yield losses for farmers. This is in contrast to passive rises in water levels, which force farmers to investigate alternative business strategies to remain profitable.[70] Dairy farmers, for example, can look at other cow breeds that are more robust or, like arable farmers, can consider growing other crops (e.g. saline crops or paludiculture). Lighter machinery and more extensive management allow ground to be tilled under wetter conditions. Other options for farmers include diversifying into recreational activities or selling local produce.[78][79]

Realisation: The costs depend very much on the package of rewetting measures. The construction costs of underwater drainage for the farmer, for example, have been calculated at an average of €1,500-2,000 per hectare.[76] A significant part of the costs also rests with the water boards, which have to make adjustments across the entire water system.

Maintenance and management: The costs depend very much on the package of rewetting measures. The annual costs of depreciation and maintenance of underwater drainage have been calculated at €200 and €300 per hectare, respectively. The estimated cost of level fixing is higher, partly because of yield losses. However, if this stops subsidence, damage to farm buildings will be prevented. This is estimated at €5,800 per hectare by 2100.[70] In addition, the water boards will bear most of the costs of maintenance and management for rewetting on a larger scale.

Examples

The Peat Innovation Programme explores and develops methods for preserving peat and researches the effects of rewetting on the agricultural sector, nature and the landscape

Research labs in the provinces of Friesland, North Holland, Utrecht and South Holland in which various rewetting measures are applied

Wet crops - Growing *Typha latifolia* (cattail) in rewetted peatlands

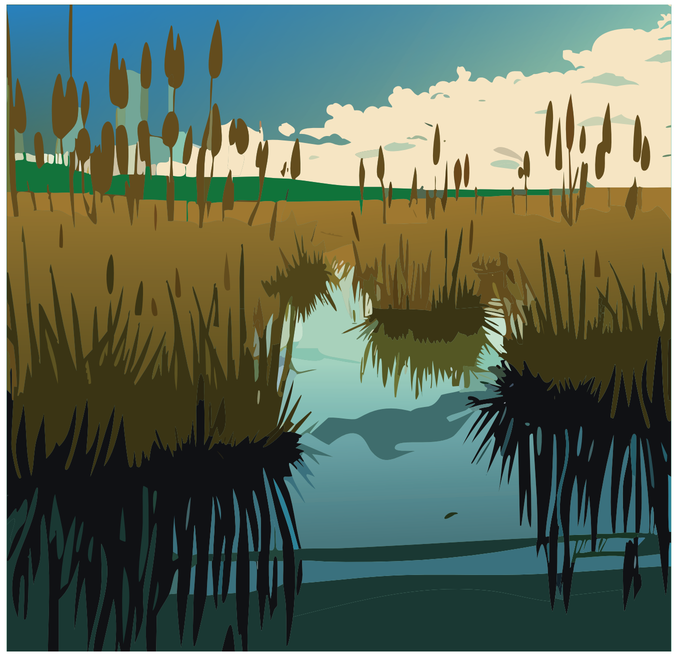
Natural Water Purification

Improving water quality through natural purification processes by using flora, fauna and subterranean features.

Introduction and challenges

Climate change can affect water quality in our water systems as a result of heat, lengthy periods of drought and flooding. This can include increased evaporation in higher temperatures, leading to higher pollutant concentrations, and greater runoff of pollutants into surface water in heavy rainfall events.[80] [81] The availability of sufficient good-quality freshwater is essential for our economy, public health and natural wetlands.[82] This is because surface and groundwater is used for many different purposes in the Netherlands, for example as a source of drinking water, to irrigate agricultural crops and as process and cooling water in industry. Sufficient freshwater of the right quality is also very important for natural wetlands, in order to maintain specific natural values. A key objective of water management in the Netherlands is therefore to protect and improve chemical and ecological water quality.[83] [84] Although water quality has improved substantially over the past decades, the quality of Dutch waters is still inadequate in many places.[85]

Ensuring clean, safe water therefore requires constant efforts. One of those is purifying water. Water purification is not only used to make groundwater and surface water suitable for certain purposes, such as drinking water, but also to remove contaminants from wastewater before it is returned into the surface water. Besides the use of technical wastewater treatment plants, flora, fauna and subterranean features can also be used to purify water before or after use. In addition the water quality of surface water can be improved, for example by removing nutrients from runoff water in agricultural areas before it enters the surface water system. This is referred to as natural water purification. Examples of this include the uptake of nutrients by plants such as reeds and floating aquatic plants, filtration of drug residues from the water by mussels and removal of viruses and bacteria through sand filtration in the dunes.[86] [87]



Artist's impression of Natural Water Purification, in which reeds absorb excess nutrients.

Societal contributions

Climate adaptation and mitigation: If natural water purification is applied as part of the water purification chain for drinking or wastewater, it can result in the purification process having a lower CO_2 footprint due to the reduced use of energy or chemical additives in the wastewater treatment plant. Natural purification can also help to reduce emissions of other greenhouse gases such as nitrous oxide (N_2O) and methane (CH_4).[88]

Biodiversity: The use of natural purification can benefit the ecological water quality of the natural water system. For example, the ecological water quality of urban water improves when rainwater runoff is purified before it enters the surface water, and the surface water into which effluent from sewage treatment plants is discharged benefits if the effluent undergoes secondary natural purification.[86] Furthermore, natural purification can itself increase species diversity in an area, as it can bring about an expansion or improvement in plant and animal habitats.

To this end, the design of a natural purification system will have to strike a balance between the purification function and the intended contribution to biodiversity. From a biodiversity point of view, another concern is that nutrients and pollutants can be absorbed into the food chain, either by being taken up directly by aquatic life or, for example, if the flora used for purification forms a food source for water birds. This is a point for consideration in respect of both the design and management of a natural purification system.

Health: Natural water purification can help to improve the quality of surface water, which benefits its quality of use. Surface water is used intensively for recreation purposes in summer, with the use of surface water for swimming expected to increase due to climate change. This also increases health risks, as the quality of swimming water deteriorates at higher water temperatures in summer. Plants such as helophytes help to mitigate surface water warming by reducing solar radiation and providing shade. [80][89]

Key considerations for implementation

Local environment: This NbS can be applied in all landscape types, but the potential and possibilities differ depending on the landscape type. For example, sandy areas (areas with cover sand, push moraines, dune areas) can be of interest in view of the purifying effect of the sandy soil; river areas given the presence of river water; and peatland areas because of the naturally wet conditions in which purifying flora such as reeds and cattail thrive. [90]

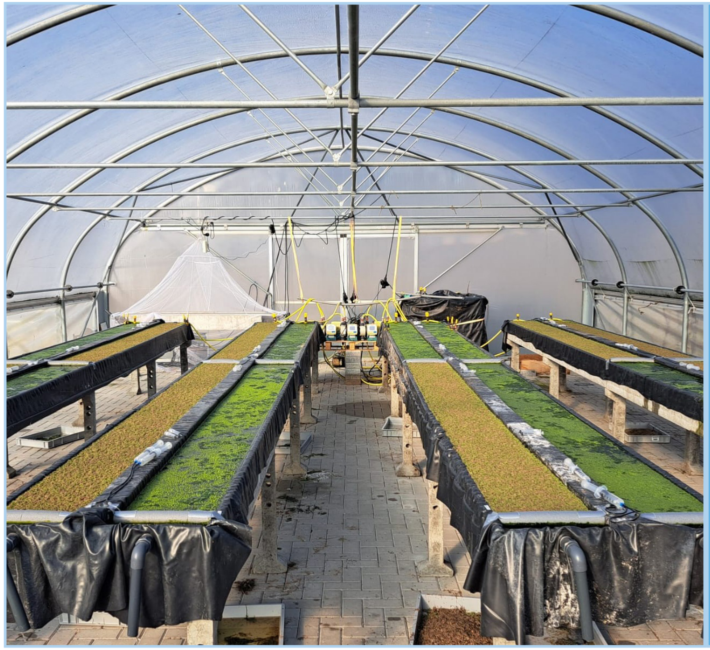
Scale: The extent of purification depends on the quantity and quality of the water to be purified. This can range from one or a few hectares (e.g. the Erasmusgracht helophyte filter: 2.25 ha) to several hundred hectares (e.g. Zuiverend Landschap: 150 ha). These natural processes often take up more space than more technological systems.

Costs

Land: The implementation of natural purification incurs potential costs for the acquisition of the land or water area in which the purification system is to be installed.

Realisation: The construction of a natural purification system entails costs for aspects such as earthworks, planting, as well as the construction of pipes, pumps and other supporting technical infrastructure.

Maintenance and management: Depending on the type of natural purification, maintenance and management costs can be incurred for mowing, aeration, pumping and silt removal and disposal. Besides costs, however, this also delivers benefits: for example, raw materials can be supplied from the purification system for other purposes such as the use of the biomass from mowings of helophyte filters as insulation and construction material; or the use of nutrients resulting from the farming of macrofauna in wastewater as ornamental fish food.[88]



Examples

Helophyte filter in Amsterdam - Purifying rainwater with a helophyte filter in the Erasmusgracht

Zuiverend Landschap (Purifying Landscape) as part of the Ijsselmeer Climate Buffer

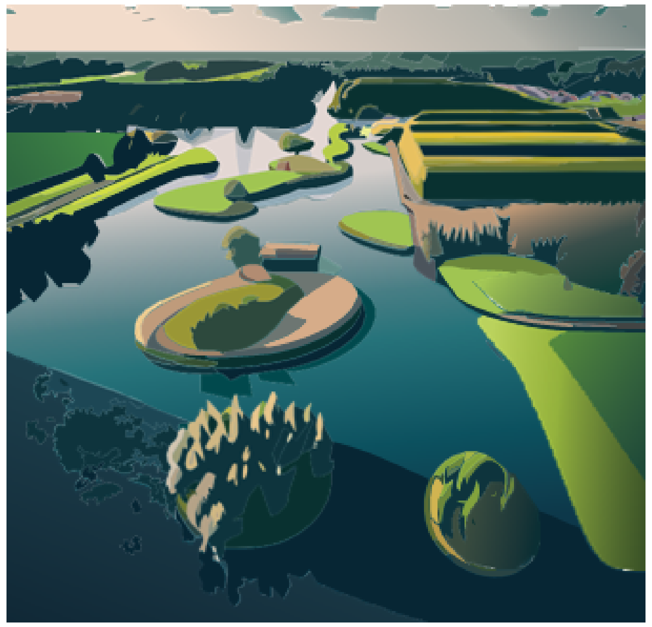
Cattail plants absorb nutrients that are released after rewetting

Freshwater Storage

Retain water by restoring the landscape's sponge effect for recharging ground and surface water and storing rainfall.

Introduction and challenges

The Netherlands is growing, both in population and economic terms, which of course means that the demand for fresh water is also on the rise. Meanwhile, climate change is increasingly, causing weather extremes that make flooding events more frequent, while droughts and higher temperatures are leading to water shortages. The desiccation of nature is an indication that we are using and discharging more water than we are storing. Farmers are increasingly struggling with desiccation and associated yield losses. Irrigation is expensive and highly labour-intensive. All this calls for a different approach to the way we use our water and design our water system. In the Netherlands, there is an average surplus rainfall of 300 mm per year in the winter months. In spring and summer, this surplus turns into a precipitation deficit. To avoid drought in spring and summer the surplus needs to be stored in winter. This can be by restoring natural processes such as soil infiltration, meandering and the sponge effect of the soil. Natural low lying areas need to regain their surface water storage function, while natural high grounds play an important role as infiltration areas. Depending on the landscape type involved, different measures can be taken to achieve this (see the Climate Impact Atlas for more information[67]). A general measure that contributes to freshwater storage is to increase the organic matter content in the soil, which will boost its water holding capacity.



Artist's impression of Freshwater Storage, in which space has been created for water storage to cope with peak loads in the water system.

Societal contributions

Climate adaptation and mitigation: Drought in peatlands and peaty stream valleys produces greenhouse gas emissions.[67] Increasing freshwater storage reduces emissions and this and helps to boost carbon sequestration through the formation of peat and restoration of woodlands etc. (see also 'Rewetting').[77] By storing and retaining freshwater, we are better able to overcome dry periods, often in the summer.

Biodiversity: Groundwater-dependent nature is under particular pressure as a result of desiccation. Freshwater storage can therefore help to boost biodiversity. However, this is highly dependent on other factors such as the landscape ecological system in question and how it is managed. Ideally, this NbS will contribute to the restoration of natural systems on a large scale, so it is expected to play a significant role in improving diversity and species.[73] On the other hand, if the quality of the inundation water is poor, water storage can also lead to problems for fragile, nutrient-poor nature. This is therefore an important consideration.

Health: Freshwater storage is of great importance for public health. Without effective freshwater storage, there will be increasingly more floodings and water shortages. At the same time, natural restoration of the water system leads to more landscape variation, for example with thickets that capture particulate matter.[77] There are trade-offs to be had here, however, as tall-growing vegetation combined with standing water increases the risk of vector-borne diseases carried by insects (see also 'Rewetting').

Key considerations for implementation

Local environment: Almost all landscape types in the Netherlands offer opportunities f or freshwater storage. These include utilising tidal marsh areas for temporary surface water storage and utilising natural levees and alluvial ridges for soil infiltration. The Climate Impact Atlas provides a complete overview of the options for each landscape type.[67]

Scale: Natural freshwater storage requires a landscape-scale approach. The effectiveness of this measure can only be ensured if cohesive measures are taken throughout the entire catchment or water table area.[91]

Costs

Land: The bottom line for this NbS is that there must be more space for water. This requires us to adopt a different attitude towards water. Natural freshwater storage can take up a lot of space, but this need not be the case if we change the way we handle water. For example, farmers can make adjustments to their crops or engage in land exchange, which allows a farmer suffering from desiccation downstream to move further upstream where more water is available due to re-meandering. The agricultural land comes available in this way can be used for creating wetlands, for example, which in turn offer recreational opportunities.

Realisation: The realisation costs of freshwater storage vary greatly depending on the extent of the package of measures, which in turn depends on the options in the area concerned. A survey of re-meandering projects by the Regge and Dinkel water board shows that the average price per hectare is around €50,000. The largest cost component is land acquisition.[92]

Maintenance and management: This NbS is based on restoring as much as possible of the natural dynamics that do not need maintenance and management, leaving room for adaptation to changes in conditions such as the climate. Natural succession also plays a role, for example by turning inundation areas into elder thickets. This has virtually no impact on the storage capacity of these areas. Fully natural system restoration is impossible due to the land-use functions already present in an area, meaning that some degree of maintenance and management cannot be ruled out.

Examples

Kempen-Broek - Area development to connect natural areas and improve water retention

The Onlanden climate buffer - Nature reserve designed to retain water and develop nature [82]

Castricum Clean Water Valley - Natural climate buffer for increasing the supply of freshwater and improving nature [82]

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Shutterstock.com
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