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State of the art of Nature-based Solutions in Iceland

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Table of Contents

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1 Summary

Nature-based Solutions (NBS) are ways to tackle climate change while at the same time increasing biodiversity and delivering ecosystem services to humans.

While there are many international reports on NBS, there is a need for an overview of NBS covering the breadth of Icelandic ecosystems. This document aims to summarize the State of art in NBS in Iceland.

2 Introduction

NBS are focused on restoring soil, forest, wetland and coastal ecosystems, enhancing their carbon storage capacity. However, NBS also aim to address societal challenges. For the successful implementation of NBS, a deep understanding of nature and the impact of humans on it is needed.

This document is based on all steps that have been taken to define the state of art in NBS in Iceland, including list of projects that could potentially be defined as NBS. The findings show that despite the usefulness of NBS projects in mitigation, adaptation, restoration and environmental protection, NBS have not been fully recognized, developed and implemented in Iceland.

Many institutions have experience in and are responsible for such mitigation, adaptation, restoration and protection projects indirectly, and some have investigated certain types of NBS in detail, but often under another name such as ecosystem restoration, natural hazard response, climate change mitigation, climate change adaptation, sustainable development and green infrastructure construction.

2.1 What are Nature-based Solutions?

The term Nature-based solutions (NBS) was first mentioned in 2008 by the World Bank (World Bank, 2008). NBS are the latest contribution to the green concept family. Many of the large international organisations have mentioned the concept in different reports. The IUCN conceptualize NBS as an umbrella term for ecosystem-related approaches (e.g., ecosystem services, green infrastructure, ecosystem-based adaption and disaster risk reduction, etc.), and in short NBS are defined as actions based in nature addressing societal challenges (IUCN, 2009 and 2012). In 2015, the concept of NBS was launched as a major research area within EU research which led to further discussion in the academic community, policy and practice (Hanson et. al, 2022).

Figure 1. © 2020 IUCN, Global standard for Nature-based solutions

2.2 Introduction to the S-ITUATION project

The Nordic Council of Ministers has launched a research programme running from 2021 to 2024, encouraging the Nordic countries to work together and enhance their knowledge base on nature-based solutions, restoration, climate mitigation and blue/green infrastructure.

Iceland took part in this four-year Nordic cooperation project (Nordic cooperation, 2021) on Nature-Based Solutions (NBS) and the guideline for the cooperation of the International Union for Conservation of Nature (IUCN) Standard (IUCN, 2020).

AUI has been involved in the first of five projects under this programme, called S-ITUATION. The project aimed to synthesize and present existing research on NBS relevant to the Nordic context, including projects and experiences, policies, knowledge gaps and cost-benefit analyses. The results of this one-year collaboration between different partners were reported to Nordic Ministers on 1st November 2022.

Further information about the project can be find here: https://nordicsituation.com/

3 Methodology and approaches

3.1 Grey literature review

Iceland has a specific context in that, although it is sparsely populated, most people live in the urban setting of the greater Reykjavík area. Nature-based solutions have not often been focused on the Icelandic context until now. Solutions tend to be rather engineering focused than purposeful nature-based solutions. The concept is new to Iceland, but national and regional authorities are starting to embrace it which may lead to increased demand of funding available for true NBS projects. Societal challenges these projects need to address range from flood hazards, habitat regeneration to increase biodiversity and plant life, wetland restoration to coastal and marine protection.

The grey literature search for Iceland was undertaken between December 2021 and June 2022. First, the English and Icelandic terms (náttúrulegar lausnir, náttúrumiðaðar lausnir) for NBS were searched, but yielded only few results. Then, national authorities' and agencies' websites were targeted, such as The Environment Agency of Iceland (Umhverfisstofnun), The Icelandic Environment Association (Landvernd) and the Government of Iceland with its ministries. Next, search engines were used, starting with google scholar for academic papers, Skemman, a repository of academic and research documents, and finally google. Furthermore, all regional websites (Iceland does not have regional governments as such) were targeted, as well as 15 local authorities (the ten most popular ones and five random ones). With this initial search, only eight relevant results were found. Of those, four came from the government, three from academic papers and one from Reykjavik municipality. Table 1 shows that all ecosystems were targeted and yielded results, albeit only generating one result each in agriculture and artificial ecosystems.

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

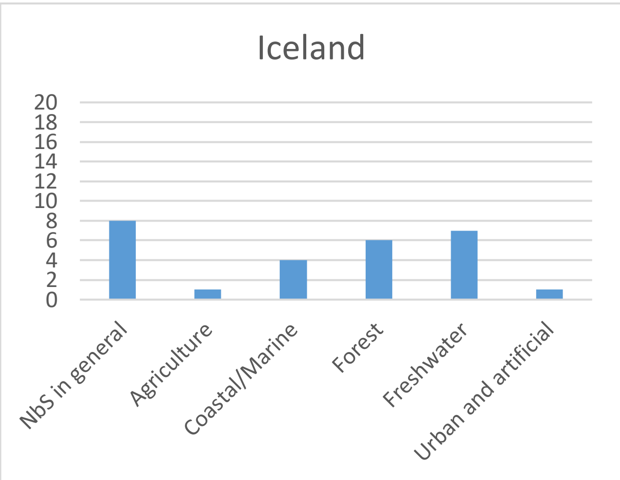


Figure 2. Ecosystems targeted by grey literature search for NBS in Iceland

3.2 Compilation of catalogue of Nordic NBS case projects

The S-ITUATION project created a catalogue with many of the NBS projects in the Nordic countries (Iceland, Norway, Sweden, Finland, and Denmark). Information included in the catalogue entries included the following: project name (local language and English), country, biodiversity net-gain, social benefits, information source, ecosystems (agriculture, marine and costal, forest, freshwater, peatland, urban and artificial and other), category (conservation, restoration and sustainable use), year when the project was established, size of the project area, societal challenges targeted (climate change mitigation and adaption, disaster risk reduction, economic and social development, human health, food security, water security, environmental degradation and biodiversity loss and other societal challenges to be described), secondary benefits, biodiversity net gain, quantified benefits, economic viability, comparison with alternative solutions, funding or financing sources and monitoring and evaluation. A total of 54 projects were added into the catalogue: 15 from Denmark, 12 from Sweden, 11 from Iceland, 10 from Finland and 6 from Norway. Three projects from each country in the catalogue were later put into the NetworkNature database: https://networknature.eu/network-nature-case-study-finder.

3.3 Icelandic stakeholder consultation

To identify NBS projects in Iceland, different stakeholders were contacted and consulted. The snowball sampling method was conducted to identify stakeholders. Two main workshop sessions were held with the leading institutions in nature conservation in Iceland. Below are the results of these workshops.

The first workshop was held November 15th 2021 online. The main Nordic stakeholders from different countries were invited to take part in a variety of workshop sessions. In this workshop with stakeholders and external participants, we aimed to:

- Learn to what degree the concept of NBS is used across different disciplines and ecosystem types.
- Introduce the IUCN global standard for NBS and discuss its applicability in Nordic Countries and in Nordic ecosystems.
- Uncover implementation barriers and knowledge gaps.
- Find out how the S-ITUATION project can extract useful and usable knowledge for their daily work with NBS.
- Give an opportunity to exchange experiences with other Nordic stakeholders working with NBS.

We found that, although most of the invited Icelandic stakeholders were actively involved in nature restoration, protection, mitigation and adaptation, there are no guidelines regarding the implementation of NBS in policy in Iceland. Even though some stakeholders have investigated certain types of NBS in detail, often other terms such as ecosystem restoration, natural hazard response, climate change mitigation and green infrastructure have been used.

The second workshop was held September 5th and 6th 2022. This workshop was focused on nature-based solutions in managing the natural water environment (*i.* náttúrumiðaðar lausnir fyrir vatnavistkerfi). The workshop was organized by ON Power (*i.* Orka náttúrunnar), Verkis hf., the Environment Agency of Iceland (*i.* Umhverfisstofnun) and the Agricultural University of Iceland (*i.* Landbúnaðarháskóli Íslands). The workshop was held in collaboration with British experts in the field of water ecosystem restoration such as CBEC-eco engineering, Salix-Building with Nature and McGowan-Environmental Engineering.

Two partners from the S-ITUATION project presented at the workshop, Samaneh Sadat Nickayin from AUI and Leonard Sandin from NIVA. Topics discussed included definitions of

NBS, a safe operating space for humanity, regulatory incentives and barriers related to NBS, blue-green solutions at a municipal level, lesson learned and examples from implementing NBS in Scotland and Norway.

A plenary session followed with three topical breakout groups: NBS approaches to river engineering and management, managing surface water from urban area and practical NBS techniques from planning, managing, and implementing peatland restoration.

The main results from the breakout session on NBS approaches to river engineering and management were that there is often no focus on NBS philosophy when choosing riverbank solutions. When choosing riverbank solutions in Iceland it is vital to recognize that different methods fit for different types of rivers. Rivers in Iceland have different sediments, some rivers change in winter conditions that can affect both the river and catchment area, and others are affected by additional natural and man-made forces.

The main result from the breakout session on managing surface water from urban area is that there is a need for legislation about NBS in urban settings, not only policies, and there is a need for more specified management plans, because often after the project is done it is not followed up. Furthermore, it is vital for more people to be involved in the decision making to find the best solution. There is a need for more knowledge on the implementation of blue-green surface water solutions in Iceland, what works and what doesn't and if native Icelandic plants are more practical in this type of implementation and then which native plants would work best. Participants also expressed a need for more funding for these projects both for the implementation and the continuing management.

The main result from the breakout session on practical NBS techniques for planning, managing, and implementing peatland restoration is that there are pressures on wetlands from tourism and summer houses as many summer houses are located in drained wetland areas. This could be resolved through managing increasing visitor numbers and by limiting tourist and summer house numbers. There is also a pressure on geothermal hot water systems and there could be a need to limit electricity and geothermal power to residents and tourists in the future. Road building projects on wetland use the wrong material in road construction projects and increased traffic and traffic impacts on roads are requiring bigger build up for road structure which has greater environmental impact. When planning NBS projects in Iceland nature should be placed first in the planning stage and should be placed at the heart of decision making and policy making. Good policies exist but they are often not put into practice. Participants in the workshop highlighted that there could be savings by implementing NBS. It was also discussed whether companies could become carbon neutral or negative by paying to fund environmental enhancement, other than planting trees. Other opportunities are to inform customers to consume less and change habits and partner with landowners to increase biodiversity, sequestrate carbon or store water and improve peatlands and wetlands. It is important to inform and educate the public of the importance of the value of nature restoration and promote and include NBS within schools and further education. On September 6th, participants took a field trip to Icelandic NBS project sites and relevant other areas, including Andakílsá, Reykjavíkurtjörn (Reykjavik pond), Vatnsmýri and Elliðárdalur.

4 Catalogue of NBS in Iceland

4.1 NBS in practice

A variety of nature-based-solutions (NBS) have been performed in Iceland in agriculture for many years. These solutions don´t have to be complicated and can be performed at several places in the country. One such solution is to close a field during the winter by using winter wheat (Triticum aesticum) that prevents the field from losing soil, carbon, and the soil´s fertility during the winter. If left bare, then the soil will blow away in winter storms. Another common solution is to grow shelterbelts around fields to protect them from wind, to increase biodiversity due to an improved habitat for animals, and to create a warmer climate in the field (Marteinsdóttir, 2022). Another substantial effort in NBS in agriculture has been the Bændur græða landið (*e.* Farmers grow the land) project launched in 1990 which engages landowners to perform land reclamation on their properties (The Soil Conservation Service of Iceland, n.d.). The project is a collaboration between the Soil Conservation Service of Iceland (SCSI) and landowners.

Although much of the Icelandic extraction industry is using coastal and oceanic resources such as fisheries and fish farming, few coastal and marine projects concentrate on nature-based solutions. In recent years, hand-crafted manufactured products have entered the food market in Iceland which are aiming to use the coastal and marine resources with minimal carbon footprint. Some contribute to building of habitats like kelp forests and thus play an important role in maintaining and improving oceanic ecosystems. Specifically, the cultivation (not just harvest) of kelp is being trialled in several projects. Kelp can be grown in the sea on lines and offers an important habitat for many oceanic species, and a nursery for juvenile fish. One company has recently started to use kelp-seeded buoys to sequester carbon from the air and store it on the ocean floor.

One way to reduce the amount of CO2 in the atmosphere is to increase vegetation, especially trees because they absorb CO2 and bind it in both wood and soil. Therefore, increasing forest cover is a good way to reduce the concentration of CO2 in the atmosphere and to reduce the effects of climate change. Forests purify the air by absorbing CO2 from the atmosphere and release oxygen (Yrkja, n.d.-c). Trees absorb more water than low-vegetation land and therefore can forests reduce the extent of floods (Yrkja, n.d.-g). Forests offer a variety of conditions for other plants, where they exchange shadows under the trees and light up in clearings. As a result, there are more diverse species of both animals and plants in forests and clearing than on barren soil. The diverse vegetation in Icelandic forests provides habitat for several animal species such as insects, birds, and some mammals (Yrkja, n.d.-a). Forests are popular for outdoor activities. They break down wind and create shelter, both for animals and plants. Studies have shown that outdoor activities in the forest have a positive effect on people´s health, as it strengthens the immune system, reduces stress, lowers blood pressure, improves sleep and much more (Yrkja, n.d.-f).

Only one NBS project was found in the freshwater category in Iceland, Andakílsá riverbank restoration project. It is important when implementing NBS on rivers to take time to get to know the river, look at the whole catchment area, type and age of river, sediment sources, erosion rates etc. It is also important to investigate changes within the catchment and the river and influences on the river, which can both be natural changes and man-made changes.

Various NBS projects relating to peatland restoration can be found in Iceland. A peatland (also called a mire) is a wetland area dominated by living peat-forming plants. They arise because of incomplete decomposition of organic matter and are an accumulation of partially decayed vegetation or organic matter, usually litter from vegetation, due to water logging and subsequent anoxia (Frolking et al., 2011). All types of peatlands share the common characteristic of being saturated with water, at least seasonally with actively forming peat, while having their own ecosystem (Hristov, 2004). Globally only about 3% of the land area is peatland (De La Haye, Devereux, & van Herk, 2021), however, Iceland's wetlands stand out with a percentage of land at 20% (The Soil Conservation Service of Iceland, 2021d). Peatlands are of essential importance to humans as they are the world´s largest carbon sink on land and store twice as much carbon as the biomass of all forests combined (De La Haye et al., 2021). Furthermore, peatlands are important for biodiversity, as some rare birds, insects and specialized plants can only be found there (De La Haye et al., 2021). 90% of Icelandic birds depend on these areas for at least some stages of their life (Óskarsson, 2021; The Soil Conservation Service of Iceland, 2021d). Peatlands in general provide many important services, such as mitigating floods, weakening droughts (De La Haye et al., 2021; The Soil Conservation Service of Iceland, 2021d), purifying water and reducing the risk for wildfires (De La Haye et al., 2021). In the past, it was only possible to walk across peatlands to visit other places in the winter, when the water was frozen, as otherwise it was dangerous, people could get stuck and die. Therefore, peatlands were not popular amongst Icelanders. The historical use of peatlands was either letting horses in to graze or digging the peat up to dry it and use it as fuel for cooking and domestic heating. In the 19th century the idea of drainage peatlands came up and many farmers started to drain (Óskarsson, 2021). From the 1940s until the late 1980s, extensive wetlands were drained for agricultural production, haymaking, and grazing that resulted in 50% to 75% drainage of Icelandic wetlands (Aradóttir & Halldórsson, 2011) and 33.000 kilometres of ditches only in Iceland (The Soil Conservation Service of Iceland, 2021b). Worldwide, 25% of wetland areas have been destroyed to date. These areas contribute a substantial 5.6% to human-induced CO2 emissions, which is more than air and sea traffic combined (De La Haye et al., 2021). It is also estimated that about 70% of anthropogenic greenhouse gas emissions in Iceland come from drained wetland (The Soil Conservation Service of Iceland, 2021c). There is a growing interest in curbing this immense release of greenhouse gases from drained wetlands through wetland restoration, by rewetting of land with organic soil (Aradóttir et al., 2013). In Iceland, the largest part of restoration activities is carried out by governmental agencies, but since the 1970s, energy companies and NGOs have taken responsibility and participated, often in cooperation with governmental agencies (Halldórsson et al., 2012). In general, peatland restoration is about refilling the ditches with material to raise the groundwater level (De La Haye et al., 2021; The Soil Conservation Service of Iceland, 2021a l.) After restoring the peatland successfully, it continues to accumulate peat and provides the ecosystem services again such as carbon storage and improving local water quality (De La Haye et al., 2021).

Blue-green water solutions are another type of NBS used in Iceland. Reykjavík city has set a policy to use more sustainable ways for treating surface water in the city by implementing so-called blue-green surface water solutions. Strategies for blue-green surface water solutions can be found in the Reykjavík Municipal Plan 2010-2030, Reykjavík city climate policy in June 2016 (i.e., increase resilience to climate change, adaptation to climate change), action plans to create environmentally friendly neighbourhoods and to conserve biological diversity (Reykjavíkurborg, 2018). In the municipal plan, eco-friendly implementations of sewerage systems and surface water pipes are taken as important factors to develop eco-friendly districts. Reykjavík city together with Veitur ohf. presented a guideline for the implementation of blue-green surface water solutions (Reykjavíkurborg, 2020) and developed an interactive map (Alta Vefsjá, 2020). The map is a useful source for both the regional plan for the capital area and the Reykjavík master plan as it shows green areas in conjunction with the urban landscape of Reykjavík, "Green Network". The green network plays an important role to plan for increasing settlements without compromising the green environment. The implementation of the blue-green surface water solutions facilitates achieving the city's goals and policies. The benefits of blue-green surface water solutions include clean surface water, increasing the natural environment, increasing biodiversity in settlements, decreasing the risk of flooding, lower start-up and operating costs of sewerage systems, increase carbon sequestration, lower maintenance costs, improving (greener) urban environment, controlling water flow and improving water quality (Eskafi, 2022).

One of the main goals of blue-green surface water solutions in urban areas is to absorb and slow down drainage in heavy rains. Water from precipitation passes through a permeable surface into the soil within the catchment area and is not discharged to conventional sewerage pipes. This reduces the amount of water in sewage treatment plants, which leads to an increase in treatment efficiency and thus discharged sewage. A key element in the implementation of blue-green surface water solutions is to ensure that wastewater does not have a detrimental effect on structures, society, and nature. Blue-green surface water solutions reduce the maximum drainage of surface water and direct and spread surface water to uninhabited areas, thus increasing flow time. The surface water chain of blue-green surface water solutions is not individual and isolated but part of a larger context, the so-called three-link surface water chain. The beginning of the surface water chain is where rainwater falls to the ground, and it ends where the water returns to the final reservoirs. The chain should be kept connected and water should be directed through the pre-defined areas. In the first link of the chain, an attempt is made to let rain descend into the soil as close as possible to the place where it falls before it carries pollutants or accumulates on an undesirable surface. It is recommended to use a permeable surface. In the second link of the chain, water is directed into vegetation and soil, or over the surface between places to be collected for a certain time where the surface water is gradually broken down, filtered, and pollutant in the water are reduced. In the third link of the chain, the excess water is directed (from the soil or on the ground) to reservoirs. Reservoirs usually cover large areas, for instance, a lake next to a settlement or wetlands. Blue-green surface water solutions are diverse and there are many options to implement them into the urban environment and can be implemented both at the start of planning in a new settlement and in already established settlement. There are several types of blue-green solutions, such as: permeable paving, green roof, soft rainwater channel (e.g., swale), hard rainwater channels, infiltration pit, rainforest (e.g., rain garden), bioretention areas, detention basin (dry), infiltration trench, filter strip, wetland, retention pond (wet), pond (e.g., basin), rainwater harvesting and underground storage solutions (Eskafi, 2022).

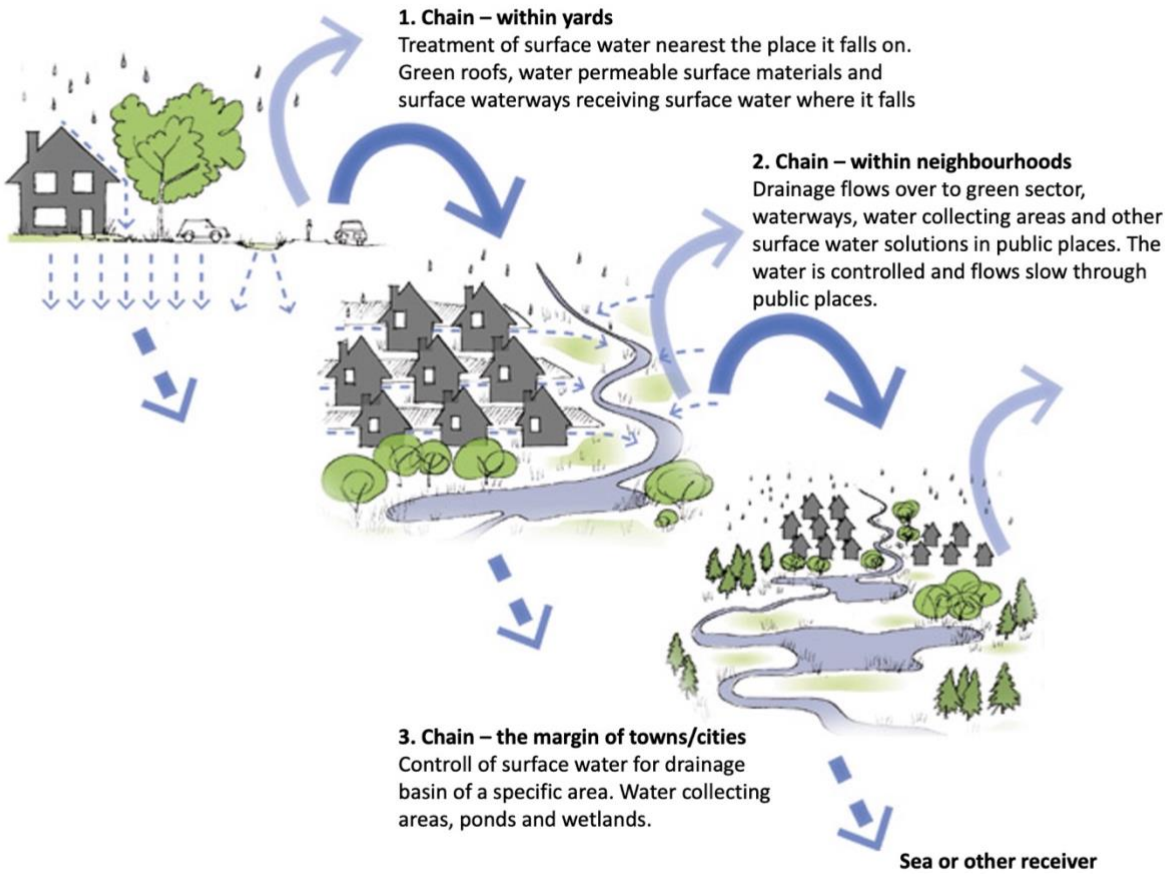


Figure 3. The surface water chain, edited figure from (Alta, 2016).

The solutions are implemented in a variety of ways, and each solution can be different in terms of appearance and various technical issues. The blue-green surface water solutions implemented in Reykjavík are e.g., rain bed, permeable surface pavement and rainwater garden. Rain beds are type of rain garden, they are vegetation beds, often lower than the surrounding environment and demarcated by edges. The water seeps through selected soil, water pollution is removed, then water seeps into the underlying soil or accumulates in drainage pipes that can be connected to a conventional sewer system (Eskafi, 2022).

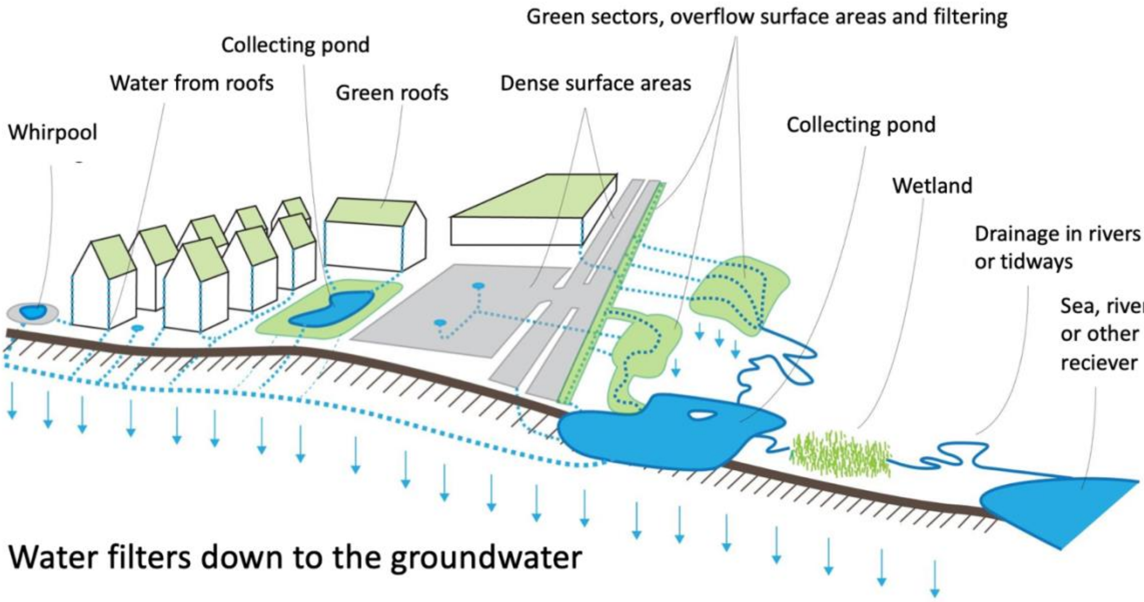


Figure 4. Blue-green surface water solutions in urban area, edited figure from (Alta, 2016).

The permeable surface pavement is a surface that is designed and implemented to allow water to flow through. The permeable surface pavements include a permeable base layer, reinforcement layer, or other substrates. They receive drainage from the surface, purify the water, slow down the flow, and direct part of the water to flow into the soil, thus helping to maintain the natural water cycle. The permeable surface pavements include a permeable base layer, reinforcement layer, or other substrates. They receive drainage from the surface, purify the water, slow down the flow, and direct part of the water to flow into the soil, thus helping to maintain the natural water cycle. Permeable surface pavement can be used in sidewalks, paths, parking lots, bicycle paths, and low-traffic streets. They are not as suitable for streets with heavy traffic or where a lot of sand, fines, soil, and leaves accumulate. The use of permeable surface pavement is not recommended in industrial areas, fuel and oil refuelling areas, or in areas where there is a risk of groundwater pollution (Eskafi, 2022).

Rainwater gardens are within plots or in green areas with special soil and vegetation that receive rainwater from gutters, sidewalks, driveways on plots, and streets and direct it into the soil. Rain gardens (usually) are not directly connected to sewer systems. Soil can filter impurities from the water and maintain nutrients for vegetation. Rain pools are a type of rainwater garden that slow down, clean, and reduce rainwater runoff and thus helps maintain a natural water cycle. They also contribute to better public health and biodiversity by increasing the green urban areas. Rainwater gardens are suitable for open areas where there is not much pollution from traffic, and it is easy to be connected to drainage from surfaces. Rainwater gardens are commonly used in private and public areas (Eskafi, 2022).

4.2 Status of NBS implementation in Iceland

4.2.1 Agriculture

There are several societal challenges caused by crop production and animal husbandry. Nutrient leakage (nitrogen and phosphorus) is a major challenge in most agricultural systems, but nutrient leaching occurs e.g., when fertilizers are added to the soils either in organic or inorganic form annually. The fertilizer is only partly absorbed and utilized by plants, whereas part of the nutrients may leach away with runoff and drainage water (Edwards, Watson, & Cook, 2012). Nutrient leaching leads to reduced water quality of freshwaters and is a major contributor to eutrophication of lakes and coastal waters (MacDonald, Bennett, Potter, & Ramankutty, 2011). Other challenges include soil erosion, loss of soil organic carbon as well as the leaching of pesticides to the surrounding land and waterways. These effects can lead to reduced soil fertility, emissions of carbon dioxide, and reduced water quality in waterways as well as a loss of biodiversity. Agriculture also affects biodiversity negatively due to the loss and fragmentation of important habitats such as meadows, permanent grasslands and small biotopes. Many red-listed species are connected to the agricultural landscape, and they become marginalized when the size and connectiveness of habitats decreases. The loss of habitats also influences the number of pollinating insects, which can negatively affect the production of crops, vegetables and fruits that need insect pollination. Intensive agricultural production requires large land-areas, and this can limit opportunities for recreational activities. On top of these pressures, climate change adds additional challenges, such as droughts, extreme rainfall and erosion, which can reduce crop yields and negatively affect animal husbandry.

4.2.1.1 Farmers grow the land

"Bændur græða landið" means "farmers grow the land" and is a collaborative project between the Soil Conservation Service of Iceland (SCSI) and landowners on land reclamation. The project started in 1990 (The Soil Conservation Service of Iceland, n.d.) but was formally launched in 1994 (Einarsson et al., 2020). Today the project has about 600 participants (The Soil Conservation Service of Iceland, n.d.), but in 2019, there were 523 registered participants in the project, of which 460 active participants (Einarsson et al., 2020). The objective of the project is to support landowners for land reclamation on their land, to stop erosion, to cover land with vegetation and to make it usable again for agriculture and other uses (The Soil Conservation Service of Iceland, n.d.).

Many municipalities support the project, along with the fertilizer factory, the budget authority, etc. BGL is one of the most successful and by far the largest projects that SCSI is involved in and has yielded a lot in the revegetation of the country (Jónsdóttir, 2007). Through the project, many hectares of unvegetated or poorly developed land have been transformed into vegetated land, soil erosion has been stopped, and many areas used for sheep today would not have met the requirements for grazing land, if it had not been systematically worked for revegetation and land improvement (Jónsdóttir, 2006). The revegetation project BGL has managed to create a very strong and close collaboration between farmers and SCSI and has proven to be an invaluable method for vegetation and soil improvement within the participants land area. The multiplier effect of this co-operation project is extremely important to everyone involved and benefits have proved to be both ecological and social (Pétursdóttir, 2009). Revegetation has several benefits such as reduced erosion, enhanced biodiversity, restored wildlife corridors, reduced CO2 output and improved visual amenity of lands and its value (Land for Wildlife Queensland, 2011).

Figure 3. Revegetation area at Kross in Ljósavatnsskarð, fertilizer application on lag gravel plain (Einarsson, Svavarsdóttir, Hjartarson, Þorvaldsdóttir, & Einarsson, 2018).

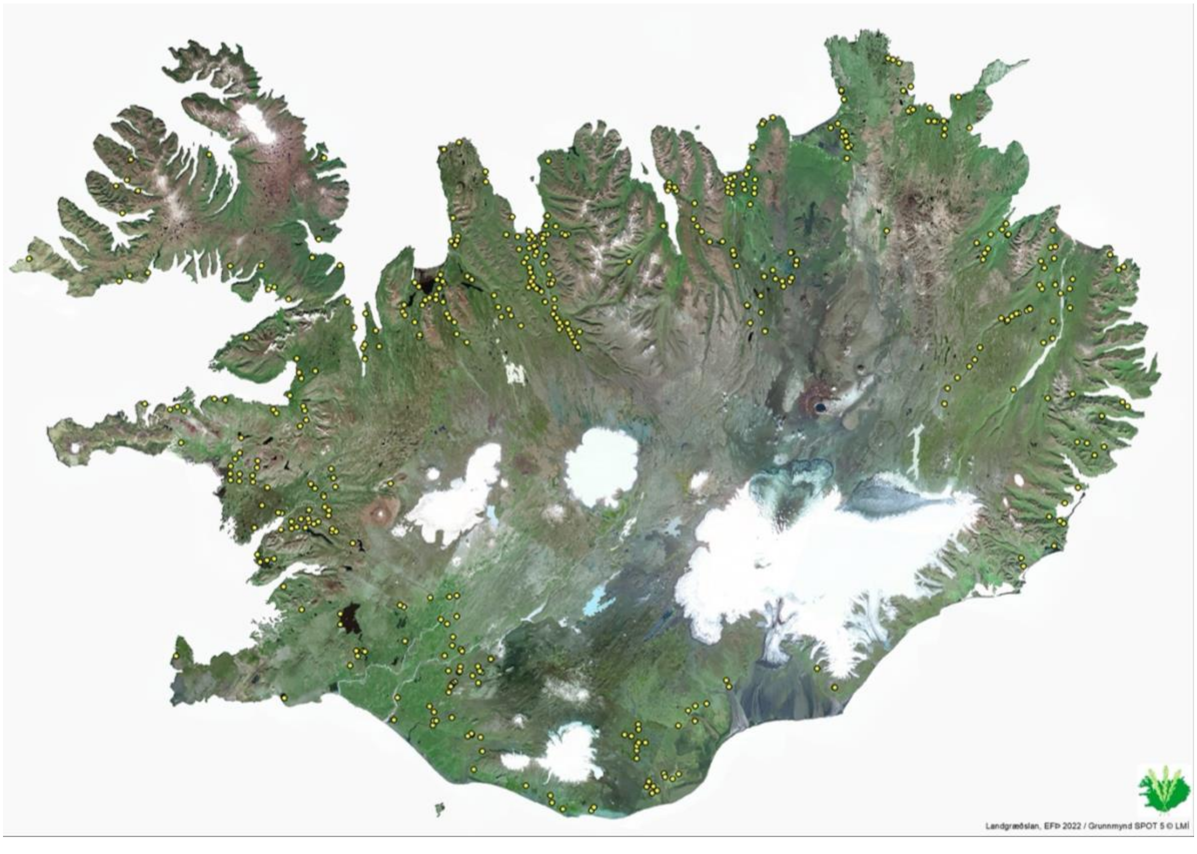


Figure 4. The distribution of participant participating in BGL in 2022 (Landgræðslan, 2022).

4.2.2 Coastal/Marine

Coastal and marine ecosystems are und severe pressure from climatic changes such as acidification, warming temperatures and sea ice melt as well as from intense human activities like fishing, pollution, shipping, construction, and drilling.

One of the main challenges is to assess and restore key habitats that will allow multiple species to recover and thrive. It is widely accepted that marine vegetation such as eelgrass and kelp play a vital role not only in producing oxygen and filtering water but also as a crucial breeding ground and habitat for juvenile fish and many other marine species.

Figure 5. Kelp forests are vital for oceanic species as well as oxygen production and carbon storage (EldeyAqua, n.d.)

Complex land-sea interactions take place in the coastal zone where life depends on the uninterrupted flow of sediments, tides and waves. In many places, these processes have been disturbed by construction of sea walls, harbours and shore development. Nature's own flood buffers like natural sand banks, kelp forests and dunes have been replaced by built structures that do not provide the same benefits. Therefore, in many places, restoration of near-shore natural conditions is a common NBS project.

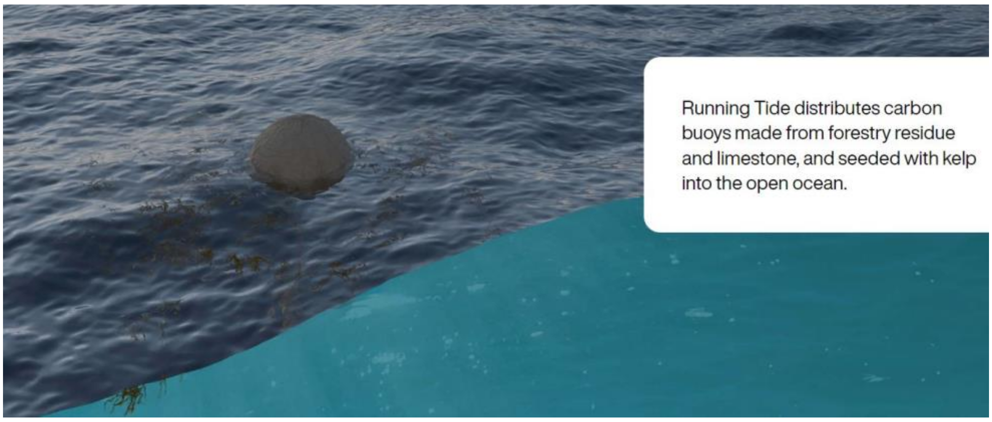
Climate change and biodiversity loss are affecting marine and coastal ecosystems severely. Species are under threat, or losing their habitat due to human activities, e.g., saltmarshes turned into agricultural land, coastal zone built up, or human-induced climatic changes such as acidification and warming of ocean temperatures. These effects on marine species can have severe knock-on effects on terrestrial species such as reduced numbers of salmon available for predators in mountain rivers due to marine pressures, but also for human activities like commercial fishing, which many communities globally depend on. Common challenges that coastal and marine NBS are tackling include climate change adaptation, disaster risk reduction and environmental degradation and biodiversity loss, with some consequences for food security (marine resource stocks).

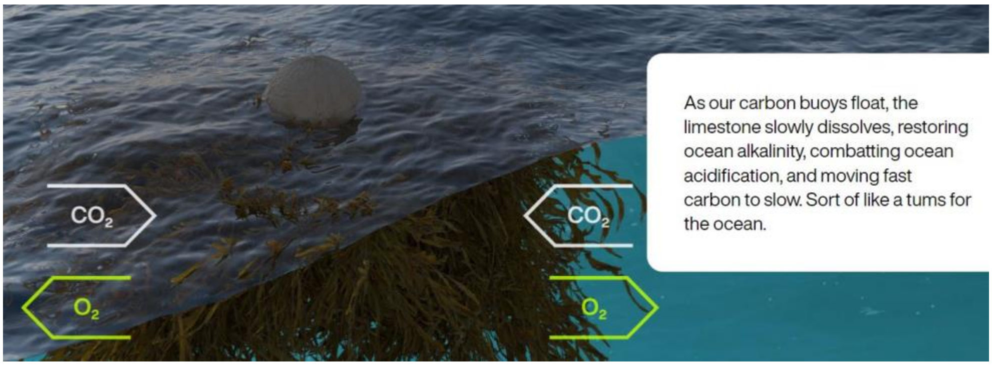
General examples of coastal and marine NBS include restoration of reefs, restoration of saltwater marshes, conservation or restoration of kelp forests, restoration of eelgrass and assessment and restoration of underwater vegetation and restoration of near-shore natural habitats which can contribute to climate change adaptation and flood risk reduction, increased water quality, increased production of oxygen, stabilising sediment and reduced risk of erosion and provide habitats for flora and fauna both in and out of the sea.

4.2.2.1 Running Tide

The Running Tide project has recently been launched off the West Coast of Iceland in the city of Akranes. The objective of the company is to sustainably amplify the natural carbon cycle by adding carbon storage sinks into the ocean. "[…] we must engage in carbon removal by transferring carbon from fast cycle sinks (i.e., biosphere, atmosphere, and upper ocean) to slow carbon sinks (i.e., deep ocean and marine sediments) " (Running Tide, 2022a, p.3).

Running Tide uses a system that amplifies three natural carbon pathways: CO2 removal by macroalgae at the surface, carbon sinking into deep ocean, and carbon removal through alkalinity enhancement. First, terrestrial biomass sourced from forestry and agricultural by-products is processed into buoys. Those buoys are placed on the ocean surface where they form a substrate for macroalgae (kelp and seaweeds) to grow on, thereby fixing carbon through photosynthesis. Then, the enriched buoys sink, transporting the fast cycle carbon to the deep ocean, which constitutes a slow carbon reservoir. Lastly, the buoys are coated with crushed limestone that partially dissolves which sequesters CO2 through alkalinity enhancement (Running Tide, 2022a).





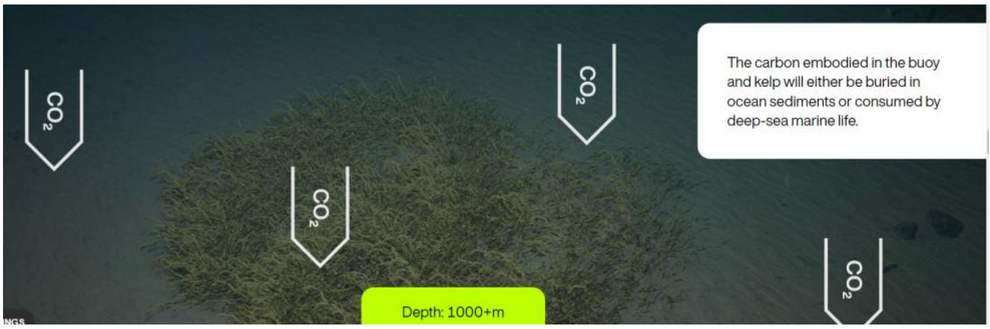


Figure 6. The Running Tide Carbon Removal System (Running Tide, 2022b)

4.2.2.2 Fine Foods Íslandica

Fine Foods Íslandica cultivates seaweed for food products to be added to soups, salads, and dishes. The seaweed is grown in Breiðafjörður in the Westfjords of Iceland. The small company produces a seafood broth using wild Icelandic mussels, sugar kelp, mushrooms and smoked fish, all of which are sourced from local producers

4.2.2.3 Norður & Co. and Saltverk

Norður & Co. And Saltverk are two Westfjords based companies that use geothermal energy and seawater to produce sea salt.

At Norður & Co. in Breiðafjörður, the seawater is filtered, and then pumped into open pans where it is slowly heated with water from natural hot springs. Inside the tank, the seawater evaporates, and the salinity level increases. When the brine has reached the right salinity level, it is transferred to open pans. It is slowly heated again using geothermal energy allowing the salt crystals to form as pyramids on the surface. The salt pyramids grow upside down and when they have reached a sufficient size they fall to the bottom. The salt is then hand harvested. Once the salt flakes have been raked from the pans, they are dried using geothermal heating. This sustainable process leaves behind no carbon dioxide (Norður & Co., n.d.)

Saltverk in Reykjanes in the Westfjords of Iceland is a newly established company producing artisan flake sea salt, using a two-century old method. 206 °F (93°C) hot geyser water from the hot springs of Reykjanes is used in the pre-heating, boiling and drying process of the salt. Geothermal energy is the sole energy source used, which means that the whole process leaves zero carbon footprint on the environment and no CO_2 and CH_4 emissions (Saltverk, 2021).

Figure 7. Salt production at Saltverk in the Westfjords (Saltverk, 2021).

4.2.2.4 Þari Þang & Eldey Aqua Seaweed cultivation

Þari Þang cultivates seaweeds for use in foods, cosmetics and other products from Flatey Island in Breiðafjörður. Sigríður Kristinsdóttir and her partner are harvesting seaweeds from the wild in Breiðafjörður, but they also attempt grow seaweed on lines in the sea. They cultivate sugar kelp (Saccharina latissima), which has showed promising results using self-seedings on ropes in the sea and then placed on mussel ropes (source: Sigríður Kristinsdóttir).

Eldey Aqua Seaweed Hatchery is based in Bolungarvík in the Westfjords and experiments with hatching of seaweeds on land and in the ocean (EldeyAqua, n.d.).

4.2.3 Forest

Today only 2% of Iceland is covered by forest but one thousand years ago around the settlement of Iceland approximately 40% of the countryside was forested. The forest disappeared because of agriculture and use of timber for housing and house heating. However, today afforesting Iceland is very much at the forefront of the Icelandic environmental plan (Chapman, n.d.).

4.2.3.1 The Hekluskógar project

Mt. Hekla is one of the largest and most active volcanoes in Iceland, and due to both eruption and human land clearance, the resilience of the ecosystem was severely degraded, meaning that extant and current geomorphological processes distribute tephra and can cause sandstorms, which pose risks to neighbouring ecosystems and human activities in the area (Bigas, Gudbrandsson, Montanarella, & Arnalds, 2009; Halldórsson et al., 2017; RECOFTC; FAO, 2012). The Hekluskógar project consist of growing birch forests and willow bushes in the vicinity of Mt. Hekla. This vegetation would reduce pumice from volcanic eruptions, thereby protecting land in the vicinity of Mt. Hekla from soil erosion (Icelandic Forest Service). The project area for this restoration by afforestation is about 1000km2, and slowing or stopping secondary tephra deposition, sandstorms and soil erosion are the primary considerations of the project, while biodiversity and ecosystem function restoration also feature prominently in the schema for management (Bigas et al., 2009; Halldórsson et al., 2017; RECOFTC; FAO, 2012).

Systems with tall vegetation are shown to endure better, and the sheltering effects of woodlands can help incorporate the ash more quickly into the soil, unlike in barren areas where wind and water erosion can cause damage further afield (Ágústsdóttir, 2015). Birch is a keystone species for many Icelandic habitats and provides several ecosystem functions. There are other candidates for such projects, but birch, being both native and pervasive, is the best-studied and has been shown to be one of the best adapted native species for afforestation as an early colonizer in degraded and eroded sites. In this context, birch seems the most desirable species for effective NBS interventions. Afforestation efforts with birch have primarily focused on the planting of seedlings, which is intensive in terms of facilities (greenhouses) and man-hours and requires direct site access (Aradóttir & Eysteinsson, 2005).

Given the large area the project is set to restore, low-cost methods are a priority, and the project relies on self-seeding from planted stands to control most of the area. Based on observations of extant birch groves rather than large-scale planting projects, small areas will be planted, and the seeds will spread forming the woodland areas over time.

The establishment of seedlings in barren areas requires soil stabilization, as well as an amendment with fertilizers if the seed is to establish a foothold. By ensuring healthy soil communities in the planted stands and not just application of fertilizer it is hoped that the natural expansion of afforested areas can be accomplished without significant fertilization, other soil amendment, or excessive amounts of labour, once the planted stands have regenerated into functional forest ecosystems (Óskarsson & Sigurgeirsson, 2001).

Outside of experiments, the planting work is mostly done by local forestry groups or by farmers, through schemes subsidized by the Soil Conservation and Forest Services (Óskarsson, 2010a). Community-based land care movements are initiatives that emphasize landowner involvement over government-directed initiatives, allowing groups and individuals to take an active part in restoration and risk management (Bigas et al., 2009). The Soil Conservation Service of Iceland has crowdsourced other aspects of this project as well, such as asking for the public's help in gathering birch seed for the afforestation projects in Hekluskógur (The Soil Conservation Service of Iceland, 2019). The National Energy Authority is legally required to mitigate environmental impacts in areas where its activities occur, the Hekluskógar project involves funding and work by the National Forestry Service and the Soil Conservation service, often carried out through local forestry groups and through the "Bændur græða landið" (Farmers grow the land) scheme which incentivizes farmers to do the work for the government on and around their own land.

Revegetation with self-seeding trees that are shown in research to do better in such environments than most other solutions will cost more to plant but be less expensive in the long run compared to previous seeding efforts with fodder grasses requiring substantial fertilization every few years (The Soil Conservation Service of Iceland). For maintenance of soil surfaces to prevent erosion from threatening hydrology this will likely prove cheaper when compared to significant earthwork maintenance in the long term as well.

Figure 8. Þórsmörk after volcanic ash deposits covered birch woodlands in the Eyjafjallajökull eruption in 2010. The forest survived and healed in few weeks (Óskarsson, 2010).

Figure 9. In 2006 strong winds from the east and northeast prevailed in the country. In such wind directions powerful wind strings are formed around Hekla which can lead to severe soil erosion in non-vegetated areas. Increased forestry and vegetation in the area will reduce soil erosion caused by this wind (Óskarsson, 2006).

Figure 10. Birch seed collection. In short, the seed collection consists of collecting birch seed cones from beautiful birch trees from the end of August to the start of October (Óskarsson, 2012a).

Figure 11. Birch seed cones (Óskarsson, 2011).

Figure 12. The birch seed are sown in a sparsely vegetated areas where competition is low (Óskarsson, 2012b).

Figure 13. A forest grows between Þjórsá river and Ytri Rangá river near Mt. Búrfell. The trees were planted in 2007 and 2008 and the photo was taken in 2012 (Óskarsson, 2012a).

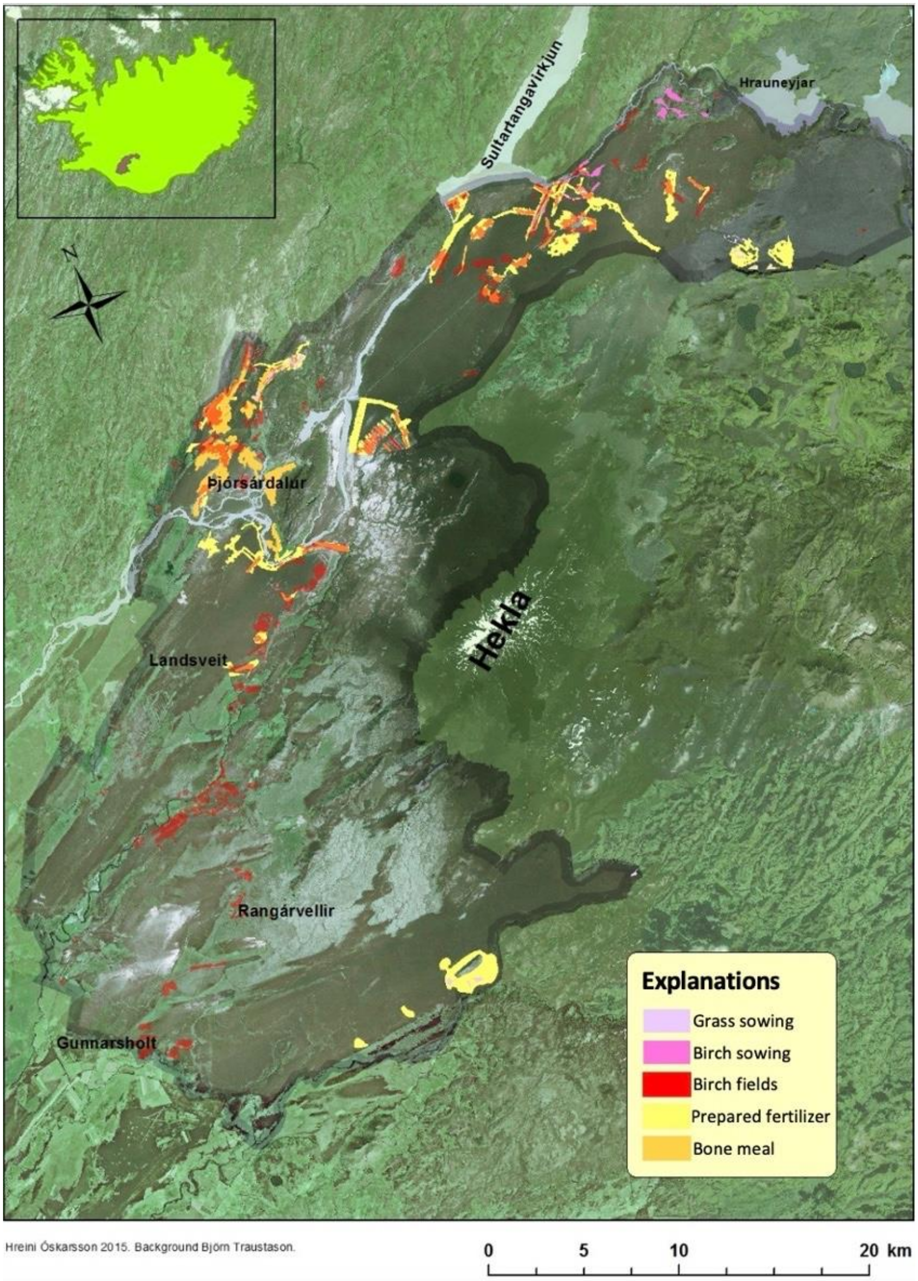


Figure 14. An overview picture showing the main construction in the Hekluskógar area in the years 2006 – 2015 (Óskarsson & Traustason, 2016).

4.2.3.2 The Icelandic carbon fund

The Iceland Carbon Fund (ICF) offers carbon offsets through tree planting, based on the ability of trees to sequester carbon and release oxygen. The ICF was founded in 2007 by the Icelandic Forestry Association and the Icelandic Environment Association, but now has its own independent board. Their goal is to decrease the level of carbon dioxide in the atmosphere and combat soil erosion, to increase public awareness of carbon emissions and their impact and provide education on related topics.

ICF carries out tree planting in Iceland in designated areas under a long-term contract, realised by local forestry associations or other contractors. The sequestration values used by the ICF are derived based on research on sequestration in Iceland, in collaboration with the Iceland Forest Service Research Station Mógilsá. So far, planting has been carried out at Geitasandur in South Iceland, Úlfljótsvatn in the Southwest and near Húsavík in the North. The plan is to have locations in all parts of the country, so that for example people from West Iceland can fix carbon in West Iceland. ICF tries to work with local forest communities, in order to use the most knowledge and experience.

ICF has an open pdf file on their website that has a detailed description of how all ICF fund procedures work in Icelandic: https://kolvidur.is/wp-content/uploads/2021/01/VerklagKolvidar_5utg_nov2020.pdf. The purpose of the fund is to fix carbon dioxide into plants and soil to take part in lowering carbon dioxide in the atmosphere. The ways in which the fund does that is by giving companies, people, and institutions the opportunity to offset their carbon footprint. They fund activities that work on reforestation and against soil erosion. ICF tries to protect plants and soil. They also expand the knowledge of the impact of carbon emissions.

ICF divides the process of their fund into 8 divisions. The first is about contracts and includes written contracts, prices, registration and information to customers. The second is providing land and includes procedures such as choosing land, rental agreements and formal registration of rental agreements. The third is forestation plans and includes a base map, starting position of carbon in the land, choosing plants and vegetation, planning of roads and infrastructure, and registration of all projects. The fourth process regards buying plants and fertilizers and includes decisions about species, choosing plant producers, contracts about plant buying, quality audit when plants are delivered, and buying of fertilizers. The fifth is about planting and fertilizing and includes choosing contractors, hiring and training, fence making, road and signs, tillage, receiving plants and storing, planting and fertilizing, monitoring and registering into a database. The sixth is monitoring and care and includes monitoring plant survival rate, monitoring fences, monitoring each site, planning for improvement, and risk assessment every 5 years. The seventh is carbon sequestration measurements and includes processes such as monitoring 5- and 10-year-old plants, projects contracts regarding measurements, measurements of carbon fixing, and registering carbon fixes into database. The final process regards return of the land and includes assessment of the total carbon fix, future planning of utilization of the forest, and a formal return to landowners.

ICF bases its carbon calculations on decades worth of studies regarding those species and places that are used. Carbon fixation builds up slowly, for the first five years it is next to none and then it accelerates up to 60 years. As a rule, money that is spent on a specific year is used to plant on the same year. Some companies make a contract with ICF about carbon fixing all their work. Some even offer their customers to fix their use as a one trip on a plane or on a car rental trip. Those companies partnering with ICF are allowed to use ICF logo in promotion purposes. On their website, ICF promotes individual carbon offsetting by buying trees that will be planted (10 trees for 2200 ISK). The average carbon footprint for an Icelander is 12 tons CO_2 per year. That matches planting 120 trees and costs 26400 ISK from ICF (www.kolvidur.is).

4.2.3.3 Yrkja fund

The Yrkja Fund was established in 1992. The fund is used to purchase plants for elementary school children to grow. This is done to introduce school children to the importance of forestry and thus raising the future foresters. The response from the schools in Iceland has been very positive, half of the schools in the country participate each day. The initial capital of the fund consisted of proceeds from the sales of the book Yrkja published in 1990 to commemorate the 60th birthday of Vigdis Finnbogadottir, then president of Iceland. Now anyone can donate to the Yrkja Fund. The Icelandic Forestry Association (Skógræktarfélag Íslands) supervises the day activities of the Yrkja Fund in collaboration with the Fund´s board (Yrkja, n.d.-e). In 2016 over 100 elementary schools participated and 8 – 10 thousand students had planted between 25.000 and 30.000 trees every year (Yrkjusjóður, 2016).

Application for the Yrkja Fund is advertised early each year and all primary schools in the country can apply for trees to the fund, whether for planting in spring or autumn (Yrkja, n.d.-e). In 2016 it was mentioned that so far it had been possible to accept every school´s application (Yrkjusjóður, 2016). Teachers can apply for grade 1 to 10 (Borgarhólsskóli, 2021) but many schools always apply for the same grades every year, e.g., grade 5 and/or 6 (Klébergsskóli, 2021; Skógræktarfélag Kópavogs). The Icelandic Forestry Association supervises the Yrkja Fund and communicates with the schools. The schools are provided with tree plants, mostly birch, and land area for the planting. These planting areas can be different between schools and between years as some of these areas have been quick to fill up (Skógræktarfélag Garðabæjar), some schools have chosen own areas to make forest near the school to use the forest more in the teaching (Borgarhólsskóli, 2021). The Icelandic Forestry Association also provides the students with planting tools necessary (Skógræktarfélag Garðabæjar). Before the trip to the planting the school children will learn how to plant trees and the importance of planting, but there is much information on the Yrkja Fund website (www.yrkja.is) on how to plant and care for trees and why planting trees is important for the environment and human health (Auðarskóli; Klébergsskóli, 2021). After the trip the teacher must fill out and send an implementation report on the planting. The teacher must fill out the name of the school and who was in charge. The teacher also must mention what was being done in the planting, what types of plants were used, was fertilizer used or not and how many participated other than the students (Yrkja, n.d.-b). Teachers are encouraged to link planting of plants from Yrkja to various subjects, through discussions or documentary work both in preparation for planting and after planting. On www.yrkja.is it is explained how the planting can be linked to e.g., food science, Icelandic, gym, religion, art, life skills, natural science, social science, mathematics, and more (Yrkja, n.d.-d).

Tree planting gives children "a sense of belonging" and can empower children into realising that they can make a personal difference for wildlife, our soil and environment. Planting trees can lead to a better mental health as research shows a correlation between childhood contact with nature and better mental health (One Tree Per Child, n.d.). This is important today as there has been an increase in stress, anxiety, and panic attacks amongst students due to exam stress (Neal, 2021). Being active will also improve children's general health and wellbeing, as well as boosting engagement more generally by providing an enjoyable context for learning. Planting trees is an easy, and long-lasting way to involve student to have a positive impact on the climate (Tyler).

4.2.3.4 CARE Rewilding Iceland

CARE Rewilding Iceland is a pilot project started in 2017 by the Icelandic Environmental Association (Landvernd, 2017a), where work is being done to improve the plants' vegetation and soil resources and the land's appearance by restoring ecosystems on land depleted of topsoil by wind erosion (Landvernd, n.d.). The project is for groups and individuals that are willing to participate in volunteering work to improve the plant and soil resources and the appearance of the country, whether it is tourists, students, or groups of employees, domestic or foreign. The goals of the project are related to e.g., nature tourism, habitat recovery, increased cultural ties between Iceland and other countries and a general awakening of awareness of plant protection. The project also contributes to increased volunteer work for the benefit of the country. The project started in the area around Mt. Hekla (Landvernd, 2017a) and has also been working in Aðaldalshraun lava in Aðaldalur (Vigfússon, 2018). The project is generously supported by the American Embassy in Iceland and the Icelandic Ministry of the Environment. Also, the Icelandic Environmental Association uses its own resources for the development of the project (Landvernd, 2019b). CARE Rewilding Iceland only uses domestic species for planting: birch, Lathyrus japonicus, Salix arctica and Leymus arenarius. Work includes stabilizing the soil surface using e.g., fertilizers and old hay, seeding or planting seedlings, or collecting seeds all depending on the season (Landvernd, 2017b).

The project exceeded expectations, with a total of 11 trips made in 2017, the plan for 2017 was to go 6 trips. A total of about 250 people worked on fertilizing, planting birch and collecting seeds. About 16,000 birch plants were planted on an area of about 40 hectares. Grants from the Ministry of the Environment and Natural Resources, The Iceland Touring Association (Ferðafélag Íslands) and WOW air enabled The Icelandic Environment Association (Landvernd) to receive all interested groups. Based on the average carbon sequestration of birch, soil, organic matter and other vegetation, the distribution of birch and its average lifespan, 14,000 tonnes of carbon dioxide will be sequestered in the area worked on in 2017 (Landvernd, 2018).

A lot of good work was done in the project in the summer of 2018. More than 300 volunteers planted 25,171 birch plants in micro-land by Þjófafoss in Hekluskógar and by Sauðafell in the North. Four tonnes of fertilizer were also distributed to the area, both in the new areas and in the area planted in 2016 and 2017. This was a considerable increase from the previous year. This large increase is a result of the cooperation and support of many parties, e.g. The Land Reclamation Agency, the Hekla Forest Project and not least the board members of The Icelandic Environment Association (Landvernd). In 2018 over 40 hectares of vegetated land was protected and reclaimed (Landvernd, 2019a).

The project includes not only work on land reclamation but also education on the history of land degradation and revegetation in Iceland and education on habitat recovery, biodiversity and climate change (Landvernd, 2018).

The project's participants are both organized tourist groups and student groups as well as Icelanders. The pilot project focused particularly on Americans to strengthen cultural ties between Iceland and the United States but in the future, it will be expanded to other nationalities. The size of the group and the exact location varies but each trip will be built around a core plan. The volunteers will meet in Reykjavík where they will travel together to the restoration site. On the way, a team leader will explain the ecology, history, and development of land degradation in Iceland. Before starting the land-restoration process and methods will be briefly explained and equipment distributed. Each trip with the volunteers takes half to one day where the groups participate e.g., in seed collection, fertilization and planting under the guidance of a team leader. At the conclusion of the day´s volunteer activities, each group places a sign at their site dedicating their work to Icelandic nature (Landvernd, 2019b).

4.2.4 Freshwater and Peatland

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

4.2.4.1 Wetland restoration in Úlfarsárdalur

From the middle of the last century, the approximately 87-hectare area in Úlfarárdalur was disturbed by drainage and cultivation for agricultural purposes. The area was drained to make fields for hay crops and grazing for horses. The drainage of wetlands in Úlfarsárdalur results in the emission of carbon in the form of greenhouse gases. The restoration of wetlands in

Úlfarsárdalur is described in the Reykjavík Master Plan 2010-2030. Verkis hf. conducted the restoration along with other environmental improvements of the area. The project was in collaboration with the Icelandic land reclamation agency and monitoring was conducted by the environment and planning department (Reykjavíkurborg, 2019). Verkis estimated that 75% of the area (i.e., 65 ha) could be restored to wetland. In April 2019, the first phase of the project for a 12-hectare area close to the municipal boundaries at Mosfellsbær was conducted. The restoration included removing debris and fences from the area, shovelling into cross-sections, and forming ponds. Then, the wetland was restored by filling up the drainage ditches using moulds from mounds in the area. Úlfarsárdalur was covered in water from the ditches and also raised groundwater. Furthermore, blue-green surface water solutions were used to provide water to the wetland and the ponds. Five ponds were formed in the wetland. The wetland vegetation was placed in the ponds to grow terrestrial vegetation again. Seeds reserves from the wetter parts of the area were transported to make up for the lack of seed reserves in other parts of the wetland. Thus, wetland vegetation grew, tufts formed, and grassland turned into swamps. To reduce the risk of erosion rocks were placed around the ditches and land was covered with vegetation. The wetland increases the biodiversity of flora and fauna. Over 50 bird species have been seen in Úlfarsárdalur and half are regular breeding birds. The ponds increased the diversity of marine life such as oysters and various wetland birds such as a variety of geese, ducks, gulls, as well as birds of prey (Verkís hf., 2016).

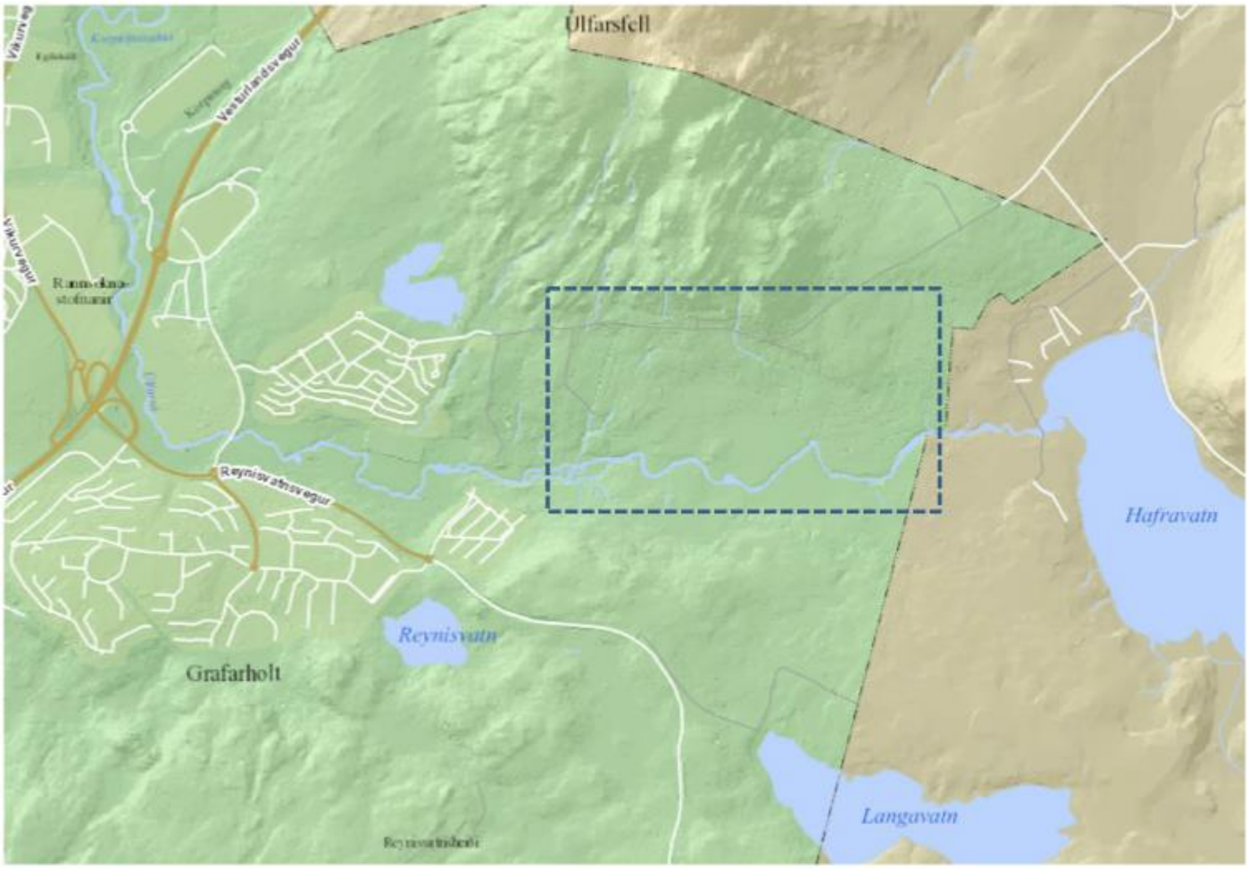


Figure 15. A map of Úlfarsdalur and the surrounding area. A rough demarcation of the observation area is shown on top of the base from Reykjvik´s City web view https://borgarvefsja.reykjavik.is/borgarvefsja/ (Verkís hf., 2016).


Figure 16. Aerial view from 1979, almost all the ditches can be seen in this photo but the ditches in the very east of the area were the last to arrive (Landmælingar Íslands, n.d.).


Figure 17. Newer aerial photo of the area from Google Maps 2022 (Google, 2022).


Figure 18. A natural stream to the east in the area that has been cut into a ditch. Looking west-northwest (Verkís hf., 2016).

Figure 19. Ditches that have been made in Úlfarsárdalur for agricultural purposes (Reykjavíkurborg, 2019).

4.2.4.2 Restoration of peatlands in Snæfellsnes peninsula

In fall 2020 the restoration of Snæfellsnes peatland begun (United Nations Decade, 2021) and was completed in December 2020 (The Soil Conservation Service of Iceland, 2021c). The area covered 100 hectares and had a total ditch length of 16 km (Hansen, 2021; The Soil Conservation Service of Iceland, 2021c). The area was chosen in collaboration with landowners that happened to have a land that lay together (Hansen, 2021). As the renaturation project was not long ago it remains to be seen how successful the work was, but in May 2021, all the filled ditches and dams were still in good shape. So far, some wetland birds have already been spotted which is a good sign in terms of increasing biodiversity (United Nations Decade, 2021). After the summer of 2021 three species have already been spotted: the black-tailed godwit (Limosa limosa), redshanks (Tringa tetanus) and the common snipe (Gallinago gallinago) (Víðisdóttir, 2021). More ducks have also been seen by landowners in the area, taking advantage of ponds and open water that has formed after the construction (Hansen, 2021). The project will be monitored closely by the United Nations until 2030 (United Nations Decade, 2021).

4.2.4.3 Restoration of peatlands in Vatnsmýri

Vatnsmýri is an important breeding area for a great variety of birds, but from 2011, few chicks have survived. This is a result of the destruction of the local peatland. Excavations had been made from ponds and house foundations, raising the surface of the land which has dried up the peatland. Furthermore, the place was used as a garbage dump for many years. The restoration project started in 2012 and was performed by the Nordic House, the University of Iceland and Reykjavík city. To restore the peatland, the old fillers like rubble and stones were shovelled out of the pond. The shovelling was also intended to get rid of unwanted plants e.g., thistle (Cirsium arvense). Thistle is one of the most prolific weeds in Iceland and it was plentiful in Vatnsmýri but it deters birds from nesting in the area (RÚV, 2012). The projected resulted in increased bird populations, especially ducks (Aradóttir, 2022).

4.2.4.4 Andakíls´ riverbank restoration project

In many places in Iceland, landslides commonly occur, and the soil is badly damaged. For example, in Andakíll in Borgarfjörður, there has been a lot of erosion for the past 50 years. Andakíls´ riverbank restoration project started in 2021 and is the first large green bank protection measure in Iceland. The project consists of using sustainable bank protection around Andakíls´ river. A natural material bank is built to strengthen it against erosion by the river. The material used in the construction of the bank protection comes from the surrounding countryside: large logs were obtained from a forest near the area and stones were also picked up to strengthen the riverbank (Björnsson, 2021; McGowan Environmental Engineering Ltd, 2021). Large wood structures in bank protection are how banks naturally stabilize, the root plate of the tree breaks off the flow actively, protecting the bank. When doing wood bank protection, holes are dug and whole trees are put in, or 5-6 meters of tree trunk, stabilised by large boudlers. Soil is set on to further stabilize, and turf set on the top which helps binding the banks (Moir & Hrafnsdóttir, 2022) and then the vegetation begins to grow and strengthen the riverbank (Björnsson, 2021; McGowan Environmental Engineering Ltd, 2021). Natural wood bank restoration protection such as was performed in Andakíll are more effective, more sustainable and lead to more biodiversity than traditional bank protection (Moir & Hrafnsdóttir, 2022). In the past, bulldozers were used, and the riverbank protected with rocks. This new method is not more expensive than the traditional methods and can be even cheaper where local materials are used (Björnsson, 2021; McGowan Environmental Engineering Ltd, 2021).

The fundamental design approach is to reproduce natural physical processes as much as is practical and allow the river to do the work. Then it is likely to be more stable and sustainable, provides greater resilience to climate change and it is more environmentally sensitive. Different approaches depend on different rivers, and there is no one size fits all approach (Moir & Hrafnsdóttir, 2022).

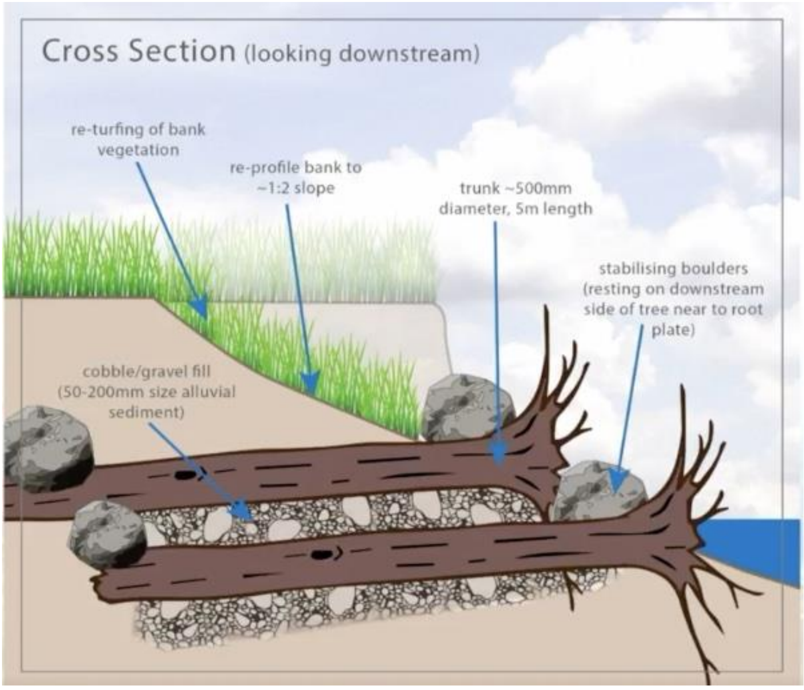


Figure 20. Cross section of how wood riverbank protection is performed (cbec eco-engineering UK Ltd).

Figure 21. Aerial photo the riverbank restoration area (McGowan Environmental Engineering Ltd).

Figure 22. Aerial photo over the area where the material used for the riverbank restoration is used e.g. big logs and stones (McGowan Environmental Engineering Ltd).

4.2.5 Urban and Artificial

Urbanisation is an ongoing trend in Iceland. In 2022, about 62% of Icelanders live in cities which is a big increase from 2000 when only 41% of Icelanders lived in cities (Nordic Statistics dataset, 2022) making NBS very important in urban settings in Iceland. Urbanisation trends, urban sprawl as well as densification have come with challenges. While urban sprawl expands the city area and converts natural areas and ecosystems into urban areas, densification can lead to reduction in area, deterioration, and overuse of green areas inside the city, so that they cannot longer fulfil their required natural functions such as temperature regulation, air filtering, absorption of rainfall or provision of recreational areas for inhabitants. These are among the challenges that urban NBS are attempting to solve.

4.2.5.1 Blue-green sustainable water solution in Urriðaholt

Sustainable drainage solutions have been designed for Urriðaholt. Urriðaholt is a new neighborhood in Garðabær, Iceland. The ecological planning of the Urriðaholt settlement is in harmony with the surrounding nature to ensure environmental protection and to maximize the quality of life of people. Urriðaholt is the first neighborhood in Iceland that receives an eco-certificate according to the Building Research Establishment Environmental Assessment Method (BREEAM) Communities certification system. This ensures that buildings in the area have minimum negative impacts on the environment and promote a sustainable society (Eskafi, 2022; Urriðaholt, n.d.-a)

The BREEAM certification system looks at five main categories of topics that aim to assess and improve the sustainability of neighborhoods. The categories are:

- Consultation and management
- Social and economic wellbeing
- Resources and energy
- Land use and ecology
- Transport and accessibility (Eskafi, 2022; Kristjánsdóttir, 2020; Urriðaholt, n.d.-a)

Urriðaholt has been recognised for its forward thinking and environmentally friendly design and planning with several international awards, such as International Award for Liveable Communities from the international organization LivCo (livcomawards.com) and awards from the Boston Society of Architects (BSA) and the Environmentally Sustainable Project Awards. Urriðaholt was also chosen by Nordregio as an example of a successful planning project in the Nordic countries. Urriðaholt includes the first large-scale sustainable drainage system in Iceland and is the only known example of a hillside application of this technology in Europe at high latitude. Urriðaholt includes the first large-scale sustainable drainage system in Iceland and is the only known example of a hillside application of this technology in Europe at high latitude (Eskafi, 2022).

The design process started in 2003 with a series of community planning exercises that involved a wide range of stakeholders. Cooperation between stakeholders, in particular, key stakeholders (i.e., clients, landowners, planning officers, local politicians, and the mayor) have been important throughout the design and planning processes (Eskafi, 2022).

A large part of Urriðaholt is within the catchment area of Urriðavatn lake. The lake and its surroundings are under environmental protection in Garðabær's master plan. Urriðavatn lake and the wetlands around the neighbourhood are home to a variety of flora and fauna. The diverse aquatic and land ecosystems depend on access to clean water. Great emphasis is placed on the maintenance and protection of Urriðavatn lake and the wetlands around it with sustainable water management (i.e., sustainable drainage solutions) (Eskafi, 2022).

Conventional sewerage solutions collect surface water from settlements in sewerage systems and then direct it to the sea (Figure 16). The utilization of conventional sewerage solutions decreases the natural flow to Urriðavatn lake and consequently has negative impacts on its shallow water ecosystem (Eskafi, 2022).

The sustainable drainage solutions mimic natural processes in the treatment of surface water to feed the lake naturally from the rainfall within the catchment area. This ensures the circulation of water in the Urriðaholt neighbourhood for the benefit of the environment and inhabitants. Therefore, the surrounding ecosystem is not disturbed and continues to thrive. They also prevent surface water causes floods due to heavy precipitations (Eskafi, 2022).

Sustainable drainage solutions are applied in the whole Urriðaholt neighborhood using swales, ponds, pipes, channels, and open green areas on the surface (Figure 24). The sustainable drainage solutions integrate a network of swales along the streets in Urriðaholt to collect rainwater from roads, parking lots, terraces, and roofs. The swales direct:

- Water to open green areas on the surface, where water can accumulate
- Water to the Urriðavatn lake
- Water by the shortest way to the soil for infiltration. This increases the natural purification of surface water and prevents pollutants to reach the Urriðavatn lake. Gradually water seeps into the lake (Eskafi, 2022).

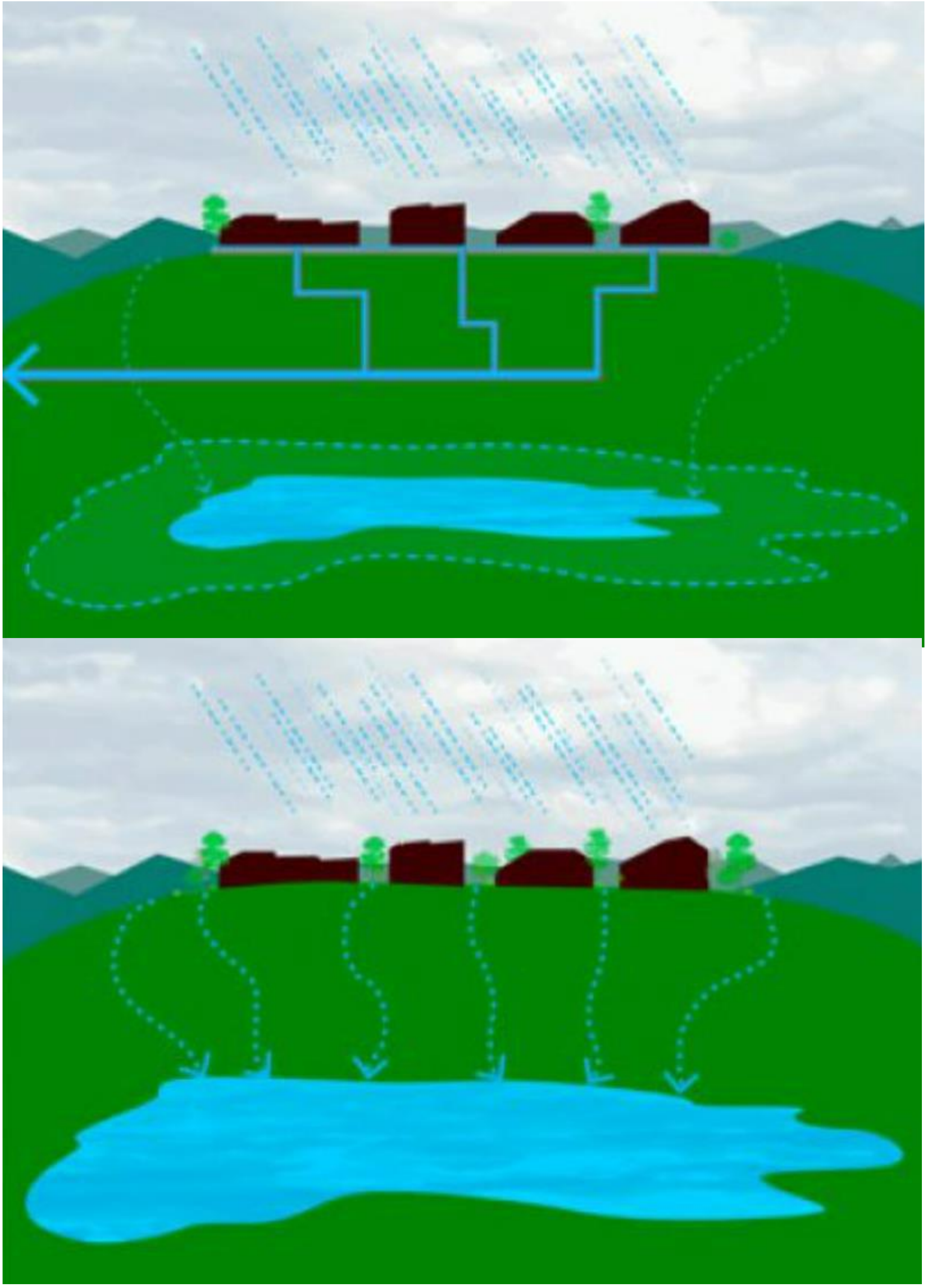


Figure 23. Difference between conventional (top) and sustainable (bottom) surface water solutions (Urriðaholt, n.d-b.).

The benefits of sustainable drainage solutions are:

- Lower cost of construction and maintenance
- Better built environment
- Healthier and more sustainable water management (Eskafi, 2022)

The water that does not sink into the soil from surface water channels, reaches collecting basins on the surface in green areas. Thus, sustainable drainage solutions increase the proportion of green open areas. Solids in the water are largely remained in the green areas or the strata and break down or become harmless before the water returns to the surface or discharged to the lake (Eskafi, 2022).

Sustainable drainage solutions are attracting attention globally to treat wastewater, instead of discharging it to a sewer system (Eskafi, 2022).

Sustainable drainage solutions effectively reduce water pollution. Studies show that they can stop over 90 percent of harmful pollutants in water that flows from streets and other surfaces before the water enters nature. They can bind metals and break down other pollutants into smaller components and thus reduce environmental pollution (Eskafi, 2022; Urriðaholt, n.d.-c)

Figure 24. Sustainable drainage solutions in Urriðaholt (Garðabær, 2006; Hauksson, n.d.; Hreggviðsdóttir, n.d.).

4.2.5.2 Blue-green sustainable water solution in Grundarfjörður

The town of Grundarfjörður started a project within street and path construction in 2021 where the walking area will be widened and improved. At the same time blue-green infrastructures will be added to the town. Rainbeds will be used that can absorb the surface water well. The project will take a few years (Grundafjarðarbær, 2021) but they will start with transforming Borgarbraut (the main street) into a blue-green street. The future plan is to transform all the roads in the village into blue-green streets as well (Pétursdóttir, 2022).

4.2.6 Other

4.2.6.1 VegVist: Restoration of vegetation during the completion of road areas

The project VegVist: Restoration of local vegetation during the completion of road areas began in 2014. From the start the project was a joint project of the Agricultural University of Iceland and the Icelandic Road and Coastal Administration (IRCA), and in 2017 Northeast Iceland Nature Research Centre and East Iceland Nature Research Centre also joined the project. The project was funded by the IRCA research fund in 2014-2015 and in 2017-2018. The purpose of the VegVist project was to promote the systematic restoration of local vegetation in areas that are disturbed by road construction, both by gaining a systematic knowledge of different options for local vegetation restoration and the dissemination of knowledge among those who work on preparation, implementation, and follow-up of road construction. In the project, measurements were made of vegetation and the appearance of roadsides and adjacent vegetation in several areas where different revegetation techniques had been applied, e.g., taking uppermost layer of soil and vegetation from the road and stockpile it and spread back into the road surface, traditional revegetation with grass seeding and fertiliser, extracting upper turf and re-applying to the road verge. Detailed vegetation measurement was carried out in the summer of 2017, which consisted of coverage assessment, tip measurement and line profile. Later, emphasis was placed on cover assessment to identify species composition and line profiles were primarily used to distinguish unvegetated and vegetated surface. The results strongly indicate that turf removal is the most effective way to restore native vegetation in a short time. Species composition diverged less from the adjacent native vegetation than observed in other roadside methods and no introduced or potentially invasive plant species in the road verges were found and vegetation typically found on human disturbed sites (ruderal species) were negligible (Aradóttir & Garðarsdóttir, 2019).

4.2.6.2 Restoration of vegetation in disturbed highland areas

The Agricultural University of Iceland and the Reykjavík Energy company started a research project in 2007 on Hellisheiði in Southwest of Iceland. The aim of the project was to test various methods for restoration of disturbed highland vegetation. The project consisted of experiments with transfer of fresh seed-containing hay and turf transplant experiments to assess the minimum turf size needed to restore heathland and grassland vegetation. Furthermore, the results of different restoration measures in the Hellisheiði area were assessed, including revegetation of road verges by transfer of large turfs from a nearby construction site and distribution of branches of the moss *Racomitrium lanuginosum* over a disturbed area. The project´s results varied depending on the type of vegetation and the methods used for revegetation. The distribution of fresh hay containing seeds and use of turfs down to 5cm in diameter led to successful colonization of many vascular plant and moss species of the grassland vegetation. On the other hand, restoration of heathland species, especially dwarf shrubs and species that form rhizomes, was most successful if large turfs (≥20cm diameter) were used. Some heathland moss species colonized successfully after the distribution of hay and shredded turfs. The transfer of turfs of grassy heathland to the roadside resulted in quick recovery of vegetation that had a similar species composition and visual characteristics to the surrounding vegetation. The distribution of the moss *Racomitrium lanuginosum* over disturbed lava slag areas appeared to accelerate its colonization. The methods used had different effects on the vegetation composition of the donor areas. While the vegetation composition of the donor area where seed-containing hay was removed was only slightly disturbed while the removal of turf represented a severe disturbance. Therefore, the removal of turf is not justifiable except on sites where construction has already been planned and the vegetation will be disturbed anyway. In those cases, care should be taken to utilize the valuable resources of vegetation and topsoil for restoration around the construction site. The selection of restoration methods should take many factors into account, including the objectives of said restoration projects, type of vegetation, availability of potential materials for restoration, costs, availability of labor and access to both donation sites and restoration sites. The design and organization of construction areas should always be aimed at minimizing the disturbance of natural vegetation, even though promising restoration methods are available (Aradóttir & Grétarsdóttir, 2011).

5 Conclusion

In Iceland, NBS are a relatively new concept. Therefore, our grey literature research yielded few direct results using this term, both in Icelandic and in English. However, the concept of NBS has been used in one way or the other in some sectors, like agriculture and in wetland and peatland restoration, as well as afforestation, for decades. Often, such projects would have been called blue-green solutions or protection measures in the Icelandic context.

Very recently, NBS as a concept has been starting to gain traction in Iceland, both in governmental communications as well as in academic circles. Workshops have been held, and practitioners from Iceland and abroad have been gathered to discuss their potential for Icelandic ecosystems and society. We expect there to be a considerable uptake of the concept in the near future, a potential increase of funding of NBS projects and increased interest by municipalities and other actors to implement them. Scientific knowledge will have an important role in indicating and filling the prevailing knowledge gaps when it comes to NBS. For example, many projects throughout the Nordic countries and Iceland lack a precise cost-benefit analysis, and therefore it remains difficult to predict economic benefits beforehand. Additionally, natural solutions take time and, if implemented only recently, will need years to show their long-term effects. As we have described, there are currently no national or regional regulations to implement NBS in Iceland, nor are there any governance guidelines that detail how they should be approached. This lack of guidance will need to be addressed in the near future as the benefits of NBS become more widely discussed and as interest in their application grows. Lastly, it is imperative that the public be involved through meaningful participation in the long-term implementation of NBS in various ecosystems.

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