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Identification and assessment of best practice in nature-based solutions for climate action and ecosystem restoration in Ireland

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Executive Summary

Climate change is a major global challenge with far-reaching consequences. Its impacts are becoming increasingly evident, affecting societies, economies, and the natural environment. The increased occurrence of extreme events including storms, heatwaves, and droughts, as well as slow onset changes in Ireland's climate, such as shifting precipitation and temperature trends, have highlighted Ireland's vulnerability to climate change and have demonstrated the need for adaptation. Impacts caused by climate change include global sea level rise, and increasing extreme weather events such as droughts, heatwaves, heavy precipitation, and tropical cyclones. Extreme heat events have impacts on human health and mortality, and have caused the loss of livelihoods and culture¹.

In response to this urgent crisis, national, international and European policy frameworks have been developed to address climate change impacts. These frameworks aim to mitigate greenhouse gas emissions, reverse biodiversity loss, and enhance strategies to adapt to projected climate impacts. A common action within these frameworks is the application of nature-based solutions to reduce greenhouse gas emissions, increase carbon sequestration and enhance societal, economic and environmental resilience to climate change.

The design and implementation of nature-based solutions is a key approach to combat climate challenges while simultaneously delivering co-benefits for human well-being, society, the economy, and biodiversity. Nature-based solutions aim to provide, maintain and/or enhance ecosystem services delivered by nature to mitigate climate change, enhance resilience through adaptive actions, and promote sustainable development while providing benefits for human well-being and biodiversity. By restoring or conserving ecosystems such as woodlands, peatlands, and urban green spaces, nature-based solutions not only sequester carbon and reduce greenhouse gas emissions but can also provide adaptation options for communities against the growing threats of extreme weather events and flooding. Additionally, these interventions offer many socio-economic advantages, ranging from job creation in sectors such as forestry and eco-tourism to improved air and water quality, which contribute to better public health. By preserving and restoring ecosystems, nature-based solutions can enhance biodiversity by providing space for nature, which in turn sustains and supports people, societies and economies, enabling us to live in harmony with nature.

This small-scale study identifies the current and emerging best practice nature-based solutions within Ireland. It pinpoints innovative nature-based solutions and initiatives that are actively contributing to climate adaptation or mitigation and provides a compendium of nature-based solutions in an Irish context. By documenting and analysing a sample of the nature-based solutions deployed to date in Ireland, a resource has been created that can facilitate the building of a comprehensive evidence base to support mainstreaming^a nature-based solutions in Ireland's environmental policies and practices. Building this evidence base is vital for informed decision-making and the integration of nature-based solutions into broader climate and sustainability efforts. This study also acts as a reference point for stakeholders engaged in the application of nature-based solutions in Ireland, to empower government bodies, organisations, communities, and individuals to implement and scale up nature-based solutions more effectively.

^a Mainstreaming nature-based solutions in this context indicates the promotion of using nature-based solutions to solve societal, economic or environmental issues as a first response where appropriate, to include them in national, regional and local policies, and have them recognised as a viable solution to climatic impacts across governmental departments and within the private sector.

This study identified a sample of 81 nature-based solutions schemes and case studies within Ireland – a complete compendium of all nature-based solutions examples in the country was beyond the scope of this project. Schemes refer to nationwide projects where nature-based solutions were actioned and supported, such as within results-based payments schemes like the Green Low-Carbon Agri-Environment Scheme (GLAS) and the Agri-Climate Rural Environment Scheme (ACRES). Other nationwide or multiple site schemes (or plans/projects) that supported the implementation of nature-based solutions include the Active Blanket Bog Restoration LIFE Project, the Strategy for Native Woodlands, and the All-Ireland Pollinator Plan. There were also site-specific projects, or case studies, such as Corkagh Park, in Dublin, the River Tolka Constructed Wetlands, and Bioswales for Flood Protection, in Ashtown, Co. Dublin (Appendix 2). All 81 examples contribute to either climate adaptation or climate mitigation. They may not have been recorded specifically as nature-based solutions, but they fall under the nature-based solutions definition used in this report, in that they solve particular issues through the provision of ecosystem services while providing co-benefits to human well-being and biodiversity.

Eight types of nature-based solutions were identified: Agroecosystem, Integrated Constructed Wetland, Urban Greening, Rivers, Peatland, Woodland, Wetland and Marine. Urban Greening solutions were the most common type of nature-based solution identified. The ecosystem services provided by the nature-based solutions in this study included carbon sequestration (48% of case studies provided this service), water attenuation^b (40%), infiltration^c (25%), coastal protection (7%), pollination (21%), pest control (10%), and nitrogen fixing in soil (7%). Nitrogen fixing in soil reduces the need for chemical fertilisers, having positive impacts on surrounding biodiversity and water courses – a bacteria in legumes and a few other plant species converts nitrogen in the atmosphere to ammonia (NH₃), which is then absorbed by the plant. This also increases below ground root biomass, which can increase carbon storage and reduce emissions^{2,3}. Beneficiaries included local communities, local authorities, landowners and farmers. Biodiversity benefits were recognised within all case studies.

While the implementation of nature-based solutions was identified across the country, their inclusion in national policy frameworks and application on a larger scale is essential to improve resilience to future climate impacts and for Ireland to become a carbon neutral island. Current barriers to the implementation of nature-based solutions in Ireland were identified and include limited funding and resources, lack of information on the implementation of nature-based solutions, along with a lack of evidence and published data on the effectiveness of nature-based solutions, and a lack of knowledge transfer from academics in this area to stakeholders wanting to apply these solutions. This report begins to address some of these issues.

Recommendations identified through this study for implementing effective nature-based solutions include:

- A comprehensive and shared definition for nature-based solutions for policymakers for implementation across sectors. A shared vision will allow for more effective monitoring and evaluation frameworks to be implemented, as it will be clear as to what constitutes a

^b The storage of large volumes of excess stormwater/rainfall within swales, ponds, wetlands, open spaces, etc., before it eventually filters through soil into the sewage system.

^c Refers to the removal of pollutants and particulates from the stormwater as it filters through soil or a permeable surface.

nature-based solution, what the outcome of an effective solution is, and what services and co-benefits they provide.

- Nature-based solutions can be implemented within multiple land and sea-uses. Consequently, responsibility for nature-based solutions cuts across multiple government departments and agencies so will either require a dedicated cross-departmental unit or assignment to an existing unit with a mandate to work across government departments/agencies/units. Key departments include the Department of Agriculture, Food and the Marine, the Department of the Environment, Climate and Communications, the Department of Rural and Community Development, and the Department of Housing, Local Government and Heritage.
- High-level national and international policy ambitions on nature-based solutions need to be translated into sectoral policies and action plans to ensure effective and coordinated implementation of nature-based solutions.
- Further funding supports for nature-based solutions in Ireland and the integration of nature-based solutions into existing climate-related funding schemes are required.
- A permanent national database of nature-based solutions that have been implemented across sectors in Ireland, maintained by a unit within a government department or agency with responsibility for nature-based solutions. This should be freely available, and easily utilised by stakeholders looking to apply nature-based solutions to specific issues.
- Monitoring and evaluating the effectiveness of nature-based solutions is essential to determine if these solutions are having a positive impact, how they are impacting the surrounding landscape over time, how the solutions respond to future climate impacts, and if there are any weaknesses within the solution. Evaluating these solutions is also vital to ensure they are providing expected co-benefits for humans and biodiversity, while also solving the climate issue they have been deployed to tackle. The use of standards, certification and natural capital accounting in monitoring and evaluating the effectiveness of nature-based solutions is recommended.
- Determine the complete area covered by nature-based solutions in Ireland, including those not defined as such. This would assist in understanding how much further Ireland will need to go with nature-based solution implementation for climate adaptation and mitigation.
- The purpose, context, and location when deciding to implement a nature-based solution, needs to be examined and nature-based solutions may not always be the most appropriate measure. Consideration of how nature-based solutions will impact a landscape before implementation is needed. For example, the “right tree right place” approach, ensuring that carbon sinks such as peatlands are not being afforested. How nature-based solutions will impact society and the economy also need to be considered before implementation. Nature-based solutions can also be implemented along with technology or grey infrastructure.
- Using the right species for urban greening and other solutions. Species consideration is vital to ensure resilience of the measure to future climate change impacts, while also reducing the risk of biological invasions.
- Increase protected areas and nature reserves in Ireland, as many ecosystems already act as natural defences against coastal erosion, reduce flood risk, and reduce greenhouse gas concentrations through carbon sequestration.

- Advisory programmes for informing stakeholders on the application, monitoring and evaluation of nature-based solutions across landscapes. There are opportunities to further integrate nature-based solutions into existing advisory programmes and services.
- A collaborative approach across governmental departments, non-governmental organisations, public service bodies, local authorities and the private sector, along with engagement with local communities and a clear governance strategy, is essential for mainstreaming the implementation and monitoring of nature-based solutions at a national level.
- Delivering nature-based solutions has an important role to play for a fair and just transition towards climate neutrality and resilience. Supporting and protecting those who are most vulnerable in Irish society, and who will be negatively impacted by this transition, through upskilling and job creation in nature-based solutions is needed.

Introduction

Anthropogenic activities have been identified as the main cause for global warming, predominantly through the emission of greenhouse gases (GHGs). Global surface temperatures between 2011-2020 have risen by 1.1 °C above 1850-1900 temperatures. GHG emissions have continued to increase through the burning of fossil fuels, unsustainable land use and land use change, mass consumption and production across sectors, countries, and among individuals¹. Global warming is increasing the prevalence of extreme temperatures and weather events⁴, with climate projections suggesting a continuing increase in climate change driven events, including floods, droughts, heatwaves, wildfires, storm surges and coastal erosion^{5,6}. These events are causing detrimental impacts to our quality of life and well-being, the economy, biodiversity, and the built and natural environment. These impacts are occurring at global scale and will have increasing impacts on Ireland. Projected increased temperatures due to climate change will result in substantially reduced water resources and agricultural yields⁷, negatively impacting food security and access to clean water. Due to these projections, the Dáil declared a Climate and Biodiversity Emergency in 2019⁸, signalling a need for more ambitious action in relation to climate and biodiversity. The application of nature-based solutions (NBS) has a key role to play in reducing greenhouse gas emissions, increasing carbon sequestration and enhancing societal, economic and environmental resilience to climate change.

Study aims and limitations

This small-scale study identifies the best practice current and emerging NBS in Ireland, through literature review and consultation with experts in the field, which have exhibited the potential to mitigate climate change and its impacts or enable adaptation to the impacts of climate change. Some of the case studies identified in this review may not have been implemented as NBS, but they tackle specific climate and societal problems while also providing ecosystem services, as well as benefits to human well-being and biodiversity.

Identifying a complete catalogue of all NBS projects that have been applied in Ireland is beyond the scope of this small-scale study, therefore a representative selection of NBS from across sectors, ecosystems, and land uses were included. The beneficiaries of these NBS were identified as were the impacts they have on biodiversity, and this compilation will act as a baseline guidance document for landowners, farmers, and local authorities in applying NBS to Irish ecosystems and land uses. This study will also inform future technical toolkits for applying NBS in Ireland.

This study does not include the many urban NBS such as living roofs and living walls (indoor and outdoor) because though they have been implemented to address climate-related problems and deliver co-benefits, they are localised and not charted, mainly because they are on private buildings. In addition, urban parks and street trees are often described as nature-based solutions, but these too have been removed because with a few exceptions they are legacy green infrastructure that have been relabelled as nature-based solutions. Thus, part of the issue with making NBS better understood is that they can be mislabelled or misrepresented.

Climate Action and Biodiversity in policy and legislation

In response to the climate challenge and declining biodiversity, the Irish government has developed the following main action plans and frameworks:

- Climate Action Plan 2024⁹ – this plan has set out various targets to reach by the year 2030. These include a 75% reduction in fossil fuel emissions by deploying renewable energy sources, reducing farm emissions by 25%, and changing how land is used, including afforestation (with key target afforestation rates of 8,000 ha/year by 2030) and peatland restoration (key target rates of 33,000 ha of Bord na Móna bogs rehabilitated by 2030, with an additional 30,000 ha of exploited peat rehabilitated by 2030). Within this plan, the government has approved an “Annex of Actions”, which contains detailed steps Ireland is taking to support the delivery of high impact climate action ambition
- 4th National Biodiversity Action Plan (draft plan for public consultation)¹⁰ – this plan aims to implement a “whole of government, whole of society” approach to biodiversity, restore and conserve priority habitats and species, promote the co-benefits offered by nature, and embed biodiversity at the heart of climate action
- Carbon Budgets Programme 2022¹¹ – this programme sets out the total amount of emissions, measured in tonnes of CO2 equivalent, that may be emitted by Ireland during the periods 2021-2025, 2026-2030 and 2031-2035. Sectoral emission ceilings set out the maximum amount of greenhouse gas emissions that are permitted in different sectors of the Irish economy in accordance with the limits of the Carbon Budget.
- National Adaptation Framework 2018¹² – this Framework addresses the climate resilience challenge: to reduce the vulnerability of our environment, society, and the economy, and adapt to future climate impacts. A new National Adaptation Framework is under development for completion in early 2024. There are currently 9 sectoral adaptation plans, mandated by the NAF of 2018 and new updated Sectoral Adaptation Plans will also be developed after the finalisation of the new NAF. The following sectoral plans are highlighted for their significance in linking biodiversity conservation and restoration with climate action:
 - Climate Change Sectoral Adaptation Plan for Agriculture, Forest and Seafood¹³ – this plan seeks to build resilience to the effects of climate change and weather-related events in the agriculture, forest and seafood sector
 - Climate Change Sectoral Adaptation Plan for Built and Archaeological Heritage¹⁴- this plan aims to build adaptive capacity within the sector, reduce the vulnerability of built and archaeological heritage to climate change and identify and capitalise on the various opportunities for the sector
 - Climate Change Sectoral Adaptation Plan for Flood Risk Management¹⁵ – this plan outlines the potential risks posed by climate change on flooding and flood risk management in Ireland, identifies sustainable adaptation approaches, and promotes a coordinated approach in action and policy to adaptation measures across sectors
 - Climate Change Sectoral Adaptation Plan for Water Quality and Water Services Infrastructure¹⁶ –this plan focuses on managing the risks from climate change for water quality and water services infrastructure
 - Climate Change Sectoral Adaptation Plan for Biodiversity¹⁷ – the goals of this plan are to protect biodiversity from the impacts of climate change, and to protect and enhance ecosystems so that they can increase the adaptive capacity of people and biodiversity, while also contributing to climate mitigation

These frameworks and action plans all align with the Climate Action and Low Carbon Development (Amendment) Act 2021, which pursues the transition to a climate resilient, biodiversity-rich and

environmentally sustainable economy, committing Ireland to a legally-binding reduction in emissions of 51% by 2030 and obtaining climate neutrality by no later than 2050¹⁸. Within Europe, the European Green Deal seeks to ensure no net emissions of GHGs by 2050 and economic growth decoupled from resource use, with the overall goal of becoming the first climate neutral continent¹⁹.

Nature-based solutions in policy and legislation

There has been a recent surge in interest in the use of NBS (or ecosystem-based approaches^d), a concept which has the potential to protect us from the impacts of climate change. NBS can help to reduce the impacts of climate change through coastal protection²¹, slowing the flow of water through various retention measures²², as well as reducing GHG emissions by sequestering carbon while also supporting biodiversity and restoring ecosystem services²³. The International Union for the Conservation of Nature (IUCN) defines NBS as “actions to protect, sustainably manage and restore natural or modified ecosystems, which address societal challenges (e.g. climate change, food and water security or natural disasters) effectively and adaptively, while simultaneously providing human well-being and biodiversity benefits”²⁴. The United Nations Environmental Assembly (UNEA) resolution adopted an agreed upon definition for NBS^e in 2022, and recognised the important role they play in response to climate change and its impacts on society, the economy, and the environment²⁵.

However, there are many other definitions of what constitutes a NBS, and the definition has not yet been fully resolved even at the national level. In this study, it is recognised that NBS solve a specific problem using the provision of ecosystem services²⁶, focus on the benefits to people, the economy, and the environment, with sustainable solutions that respond to climate change and related hazards in the long-term, taking socio-economic development, human well-being, and governance principles into account²⁷. Compared to man-made, “grey” infrastructural responses to climatic events, which can be costly, require high-maintenance strategies and are largely unsustainable²⁸ as well as depreciating over time, NBS can, in appropriate locations, provide a more sustainable and cost-effective solution, along with more beneficiaries and ecological enhancement²⁹ that can appreciate in value over time. To apply NBS sustainably across Ireland, this approach must include a shared vision of what NBS are across sectors, a consistent approach to how they are designed and implemented, and a framework to help evaluate, adapt, and improve these solutions³⁰.

Under the aforementioned Irish policy frameworks, NBS have received limited attention. The Climate Action and Low Carbon Development Act 2021 defines NBS under ‘nature based project’, defining them as a “solution that is inspired and supported by the process and functioning of nature, which is cost-effective and provides environmental, social and economic benefits and helps to build resilience”¹⁸. This act states that nature-based projects to enhance biodiversity, reduce GHGs, and increase climate resilience are to be supported. It is important therefore that an evidence base for

^d There is a debate over this terminology, which derails the number one priority of agreeing an ambitious framework that can both halt biodiversity loss and deliver for human wellbeing. Representatives of Indigenous Peoples have expressed concern that NBS is a term that separates people and nature, implying that nature delivering solutions to people is a one-way relationship. The ecosystem-based approach term is preferred by them, which represents that people and nature are inextricably linked and interdependent²⁰. The ecosystem-based approach has 12 agreed upon principles under the Convention on Biological Diversity <https://www.cbd.int/ecosystem/principles.shtml>.

^e “actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services and resilience and biodiversity benefits”.

NBS is developed to enable assessment of the costs and benefits. NBS are also mentioned in the following:

- Climate Action Plan 2024⁹ – NBS feature under the Marine Environment and Adaptation chapters. Comprehensive criteria for NBS within the marine environment for carbon storage and to increase climate resilience are to be developed. Under Adaptation, the management of rainwater and surface water runoff in urban areas using NBS is highlighted. A best practice guidance document has been developed by the Department of Housing, Local Government and Heritage – “Nature-based Solutions to the Management of Rainwater and Surface Water Runoff in Urban Areas – Best Practice Interim Guidance Document”³¹ and an Urban National Implementation Strategy for Nature-based Solutions is under development. This document is for urban planners, outlining how to move towards the use of NBS to absorb, retain, store, and treat urban runoff. A Design Manual for Road and Street Drainage using Nature Based Solutions (Advice Note 5) was published by the DHLGH in June 2023.
- The Office of Public Works also has a dedicated Nature-based Solutions for Catchment Management Strategy³² to capitalise on the potential of NBS for flood reduction and to achieve co-benefits for water quality, habitat improvement, increased carbon storage, and improved soil structure. The Inland Fisheries Institute also published a guide on planning for watercourses in the urban environment, which guides on the use of buffer zones, sustainable drainage systems, instream rehabilitation, climate / flood risk and recreational planning (available here: [FIUrbanWatercoursesPlanningGuide \(fisheriesireland.ie\)](https://www.fisheriesireland.ie/urban-watercourses-planning-guide)).
- Ireland’s 4th National Biodiversity Action Plan¹⁰ (draft plan for public consultation) – Outcome 4C aims to increase the number of NBS implemented across landscapes, including urban and rural, bringing together a wide range of community groups. These NBS will combine benefits for biodiversity and climate adaptation, while also contributing to national climate ambitions under the Climate Action and Low Carbon Development Act 2021.
- National Adaptation Framework (NAF) – This framework recognises that no national level standards for NBS exist and identifies research gaps in understanding the benefits of NBS and the challenges of implementing these measures. It states that ‘green infrastructure’, which includes NBS, must become an integral part of spatial and territorial planning. It recommends that a new NAF can emphasise the importance of NBS and provide practical examples of how they increase climate resilience.

NBS are recognised within Irish policy, but their implementation needs to be further developed and supported. Integrating NBS coherently and systematically into Irish policy will assist in reaching our legally binding targets of becoming climate neutral by 2050 under the Climate Action and Low Carbon Development Act 2021, providing natural defences and absorption capacity against flooding and coastal storm surges, for example, while also enhancing biodiversity and providing co-benefits for Irish society. Mainstreaming NBS within national policy will also facilitate the integration of these solutions within local action plans, strengthening local economies while also improving climate resilience at local levels.

With the surge in interest in applying NBS to solve climate issues, policy frameworks internationally and across Europe have begun to recognise the essential role of NBS in responding sustainably to these challenges and have integrated them into various frameworks.

The Kunming-Montreal Global Biodiversity Framework (GBF) under the Convention on Biological Diversity (CBD), a major development for NBS, supports the achievement of the Sustainable Development Goals, setting out a pathway to fulfil the global vision of a world living in harmony with nature by 2050. Among the framework's key elements are 4 goals for 2050 and 23 targets for 2030, to reverse biodiversity loss and protect and enhance biodiversity and ecosystems³³. Of these targets that are to be implemented by CBD member states, two make specific reference to NBS³⁴:

- **Target 8** – “Minimize the impact of climate change and ocean acidification on biodiversity and increase its resilience through mitigation, adaptation, and disaster risk reduction actions, including through nature-based solutions and/or ecosystem-based approaches, while minimizing negative and fostering positive impacts of climate action on biodiversity”.
- **Target 11** – “Restore, maintain and enhance nature's contributions to people, including ecosystem functions and services, such as the regulation of air, water and climate, soil health, pollination and reduction of disease risk, as well as protection from natural hazards and disasters, through nature-based solutions and/or ecosystem-based approaches for the benefit of all people and nature”.

At COP27 in December 2022, the United Nations Framework Convention on Climate Change recognised NBS for the first time in the Sharm el-Sheikh Implementation Plan, encouraging parties to consider NBS for their mitigation and adaptation action while ensuring the protection of society and the environment³⁵. At EU level, NBS are recognised as key to achieving the objectives of the major EU policy priorities under the European Green Deal, particularly the EU Biodiversity Strategy for 2030 (a plan to protect nature and reverse the degradation of ecosystems), and the EU Adaptation Strategy (a strategy to adapt to the impacts of climate change), while enhancing biodiversity and making Europe more climate resilient³⁶. The EU Climate Change Adaptation Strategy of 2021 promotes the use of NBS for adaptation to climate change impacts, stating that implementing them on a larger scale would increase resilience and sustain healthy water, ocean and soils, and that Europe needs to leverage more investment in NBS³⁷. The EU Biodiversity Strategy for 2030 states that NBS which involve restoring and sustainably managing ecosystems will be essential for emissions reductions and climate adaptation³⁸. NBS will also have a key role to play in the implementation of the EU Nature Restoration Law. These high-level policy ambitions still need to be translated into sectoral policies and action plans to ensure effective and coordinated implementation of NBS.

Methodology

A literature review was completed between June and August 2023, using databases including Google Scholar, Web of Science, Scopus and TARA (Trinity's Access to Research Archive). Keywords used included "Nature-based solutions", "ecosystem restoration", and NBS concepts that are mentioned in the previous section (e.g. ICW, NB SuDS). Only studies that were implemented in Ireland were included. NBS were selected based on the following: they protect and restore ecosystems and their services to solve a specific problem, address societal challenges and provide benefits for human well-being and biodiversity, while also contributing to either climate adaptation and/or mitigation.

Databases were also searched for published work by prominent researchers in the field of NBS in Ireland. Prominent researchers were contacted via email for unpublished data in relation to NBS case studies. Related websites such as the Environmental Protection Agency (epa.ie) and the Climate Action Regional Offices (caro.ie) were searched to increase the quantity of data. A table (Appendix 2) was created to compile the NBS case studies with the following columns: the name of the project; what organisations were/are involved; the project aim; whether it contributes to climate adaptation or mitigation; what ecosystem services are delivered through the project; who the beneficiaries of the project are; what type of NBS it is; the cost of the project (€); the area (km²) covered by the project; and the county the project was implemented, along with its coordinates.

A report was drafted based on an analysis of the NBS case studies identified, their benefits and co-benefits, and the challenges of implementation in Ireland.

As a final elicitation for this study, a workshop was held on the 5th September 2023 in Trinity College, Dublin, with participants who are experts in the field of NBS (Appendix 1). Within this 2-hour workshop, the purpose of the study was detailed, along with a presentation of the results so far. A discussion was then held where recommendations of further literature to cite and other aspects to include in the report were confirmed and added.

Overview of assessed nature-based solutions projects

NBS can be implemented to combat climate challenges in two main ways: through climate mitigation and/or climate adaptation. Climate mitigation involves the reduction or elimination of GHGs from the atmosphere, while climate adaptation involves practical actions to manage, protect, and improve resilience against predicted climate impacts³⁹. Through this small-scale study, a compendium of 81 different NBS projects across Ireland was compiled (Appendix 2), representing the various NBS applied across land uses and ecosystems, that contribute to either climate adaptation or mitigation (Figure 1.), social and economic development, and enhanced biodiversity.

Overview of Climate Measures

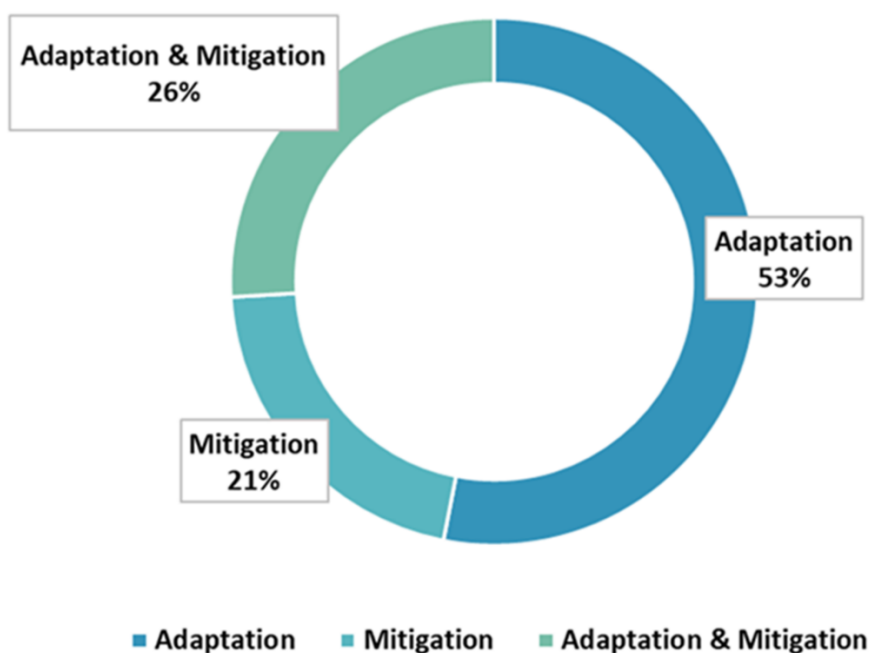


Figure 1. Percentage of NBS projects with climate adaptation target measures, climate mitigation target measures, and projects that target both.

Eight different NBS types were identified (Figure 2.): Agroecosystem, Integrated Constructed Wetland, Urban Greening, Rivers, Peatland, Woodland, Wetland and Marine. Urban Greening projects were the most common within the study at 26%. Peatland (7%) and Woodland (6%) are underrepresented, as the projects included span multiple nationwide sites, however each project is represented as one row within the table (Appendix 2).

Nature-based solutions by type

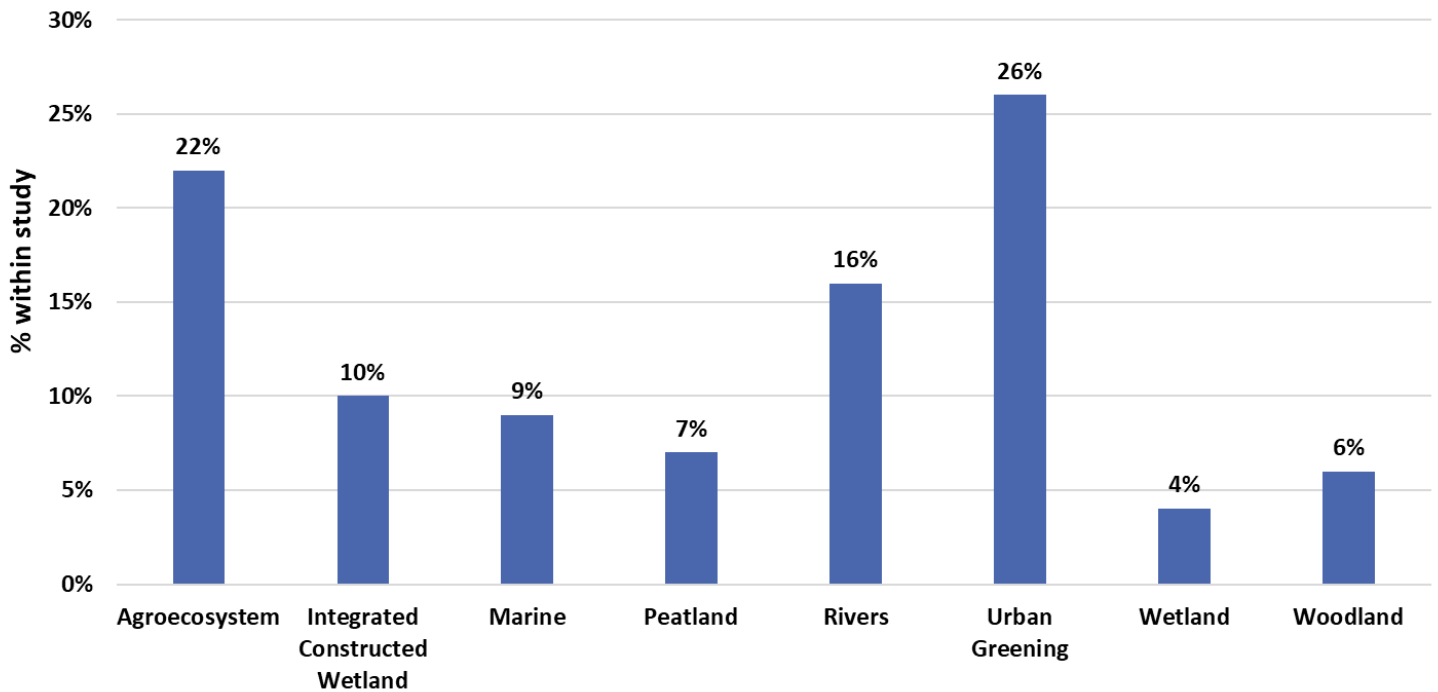


Figure 2. Types of nature-based solutions identified within the study, out of 81 projects.

The compendium was compiled from a literature review of online databases and consultation with experts in the field of NBS. A selection of NBS were chosen from across the various land uses and ecosystems within Ireland. It is important to note that this table is a non-exhaustive list of the NBS in Ireland, and that the selected projects within this table are a representation of current and emerging best practice NBS.

Various types of NBS can be implemented to mitigate or adapt to climate change, with many of the following already applied in Ireland:

- Integrated constructed wetlands (ICW), which are engineered wastewater treatment systems encompassing biological, physical and chemical processes similar to those occurring in natural wetlands⁴⁰. These wetlands can mitigate climate change by sequestering carbon dioxide (CO₂) and provide ecosystem services such as the absorption of pollutants through infiltration, improving water quality, and climate adaptation measures such as flood mitigation⁴¹.
- Peatland restoration, through rewetting by blocking drains, removing non-native conifer plantations, and replanting *Sphagnum spp.*, offers climate mitigation through reductions of GHG emissions and sequestration of CO₂⁴². Similar to constructed wetlands, the rewetting of peatlands can improve water quality through filtration of pollutants, and can store excess water to mitigate flooding. Re-vegetating peatlands will also enhance biodiversity, which increases ecosystem services such as pollination, pest control, recreation and amenity and seed dispersal services⁴³. Raising the water table on agricultural peatlands alone is estimated to deliver 2,909 ktCO₂e yr⁻¹ cumulative mitigation potential between 2021-30³.

- Nature-based Sustainable Urban Drainage Systems (NB SuDS), are a network of vegetated areas and open spaces such as green roofs, porous pavements, rain gardens, etc., that replicate natural ecosystem services, while providing a variety of benefits to people and biodiversity⁴⁴. NB SuDS replicate predevelopment catchment hydrology, attenuate stormwater run-off, and improve water quality as an adaptive measure to predicted increased rainfall^{45,46}.
- Agroecosystem approaches include:
 - Agroforestry, the integration of trees and shrubs with livestock or crops, can significantly mitigate climate change by reducing atmospheric GHGs as carbon is stored in trees and soils, while also aiding farmers in adapting to climate change⁴⁷. Integrating trees with crops can offer protection through shading from increasing heatwaves. Diversifying land use, for example through combining tree crops for timber with livestock (known as a silvopastoral system), can also allow farmers to have multiple sources of income⁴⁸, providing stability against yield fluctuations caused by extreme weather events.
 - Clover in pasture/Multi-species swards (grasses, legumes, forbs) enhance pasture productivity and decrease seasonal variability of pasture production facing more extreme weather events, such as drought, due to climate change². Multi-species swards have also shown that they positively impact cow performance⁴⁹. This measure is predicted to account for 8% of the total emission reductions by 2030³, while also providing co-benefits for pollinators.
 - Organic farming systems which produce products in a manner that is beneficial to biodiversity and the environment. It relies on ecosystem services, biodiversity, and cycles adapted to local conditions, rather than using chemical inputs such as nitrogen fertilisers. Organic farming can improve carbon sequestration through improved soil health. This is done through reduced or removed use of chemical fertilisers, crop rotation involving legumes, and the planting of cover crops⁵⁰.
- Coastal/marine defence measures, which can include a variety of NBS based on habitat, threats, and numerous other variables. NBS that can be implemented on coastal/marine systems to adapt to climate impacts can include: dune restoration²¹, where marram grass is planted to stabilise the dune system, or wooden fence posts are erected to build up sand deposits which can also stabilise the dunes. Oyster reefs are another solution which may be an effective adaptation measure, where the restoration of an oyster reef offshore can protect the coast from storm surges and coastal erosion⁵¹.
- Habitat restoration as a NBS has many benefits, both adaptive and mitigative⁵². Restoring wetlands, peatlands (as mentioned), and woodlands can reduce GHG emissions, while also improving biodiversity and associated ecosystem services such as pollination, storm and flood water attenuation, and infiltration to improve water quality. On farmland, restoring these habitats can improve soil and water quality, enhancing land productivity. Restoring coastal habitats such as saltmarshes can reduce flooding and the impacts of storm surges on coastal communities, with the restoration of riverbanks and floodplains having a similar

effect. Habitat restoration also has many co-benefits^f, such as enhancing biodiversity and creating recreational spaces for communities⁵³.

- Urban greening is the addition of green spaces such as parks, planting trees, green roofs, or other “greening” (soft, permeable surfaces such as soil, grass, shrubs, trees and water⁵⁴) actions to urban areas. These “greening” measures can reduce local temperatures⁵⁵, improve air quality⁵⁶ and reduce GHG emissions, attenuate rainwater, and improve water quality⁵⁷. Urban green areas also provide habitat for urban wildlife, which increases ecosystem services such as pollination and pest control. These areas also provide social, economic, psychological, and health benefits⁵⁸.

The above list of NBS is a summary of some which have been implemented in Ireland and across Europe to tackle specific problems, with some of these NBS examples included in the compendium of 81 projects. NBS have been implemented long before the term was coined, therefore they may not be named specifically as “nature-based solutions” in literature – the above are examples of measures which can be applied to mitigate or adapt to climate change but may not always be specifically recorded as NBS. Some studies on the application of NBS in an Irish context exist⁵⁹, and it has been argued that hedgerows, such as those in the Irish landscape, could be considered the earliest example that is still extant of a NBS⁶⁰. However, the literature relating to NBS in Ireland is poor.

The list of NBS in the table (Appendix 2) depicts the range of projects that can be implemented across land uses and ecosystems. It is clear that NBS provide multiple benefits for communities, landowners, and local authorities through the provision of ecosystem services. The services provided by the NBS case studies in this project include carbon sequestration (48% of projects provided this service), water attenuation (40%), infiltration (25%), coastal protection (7%), pollination (21%), pest control (10%), and nitrogen fixing in soil (7%) (**Figure 3.**). Each of the 8 NBS types identified in this study provided at least two of these ecosystem services. Agroecosystems provided the most ecosystem services out of the NBS types: this is due to the fact that Agroecosystems identified within the study cover a wide range of habitats (**Figure 4.**). NBS also have the potential to offer significant co-benefits, such as recreational and amenity spaces, clean air and water, reduced costs from climate events and “grey” infrastructure maintenance, and reduced GHGs. Local communities are beneficiaries in all the NBS projects included in this study. This highlights the advantages of implementing NBS, as they not only solve climate issues, but they also provide many co-benefits to the surrounding communities. Other beneficiaries include farmers, landowners, and local authorities.

^f Beneficial outcomes that are not directly related to climate mitigation or adaptation. These can include cleaner air, enhanced biodiversity, public health benefits from the creation of green spaces, and economic stability.

Ecosystem services delivered within case studies

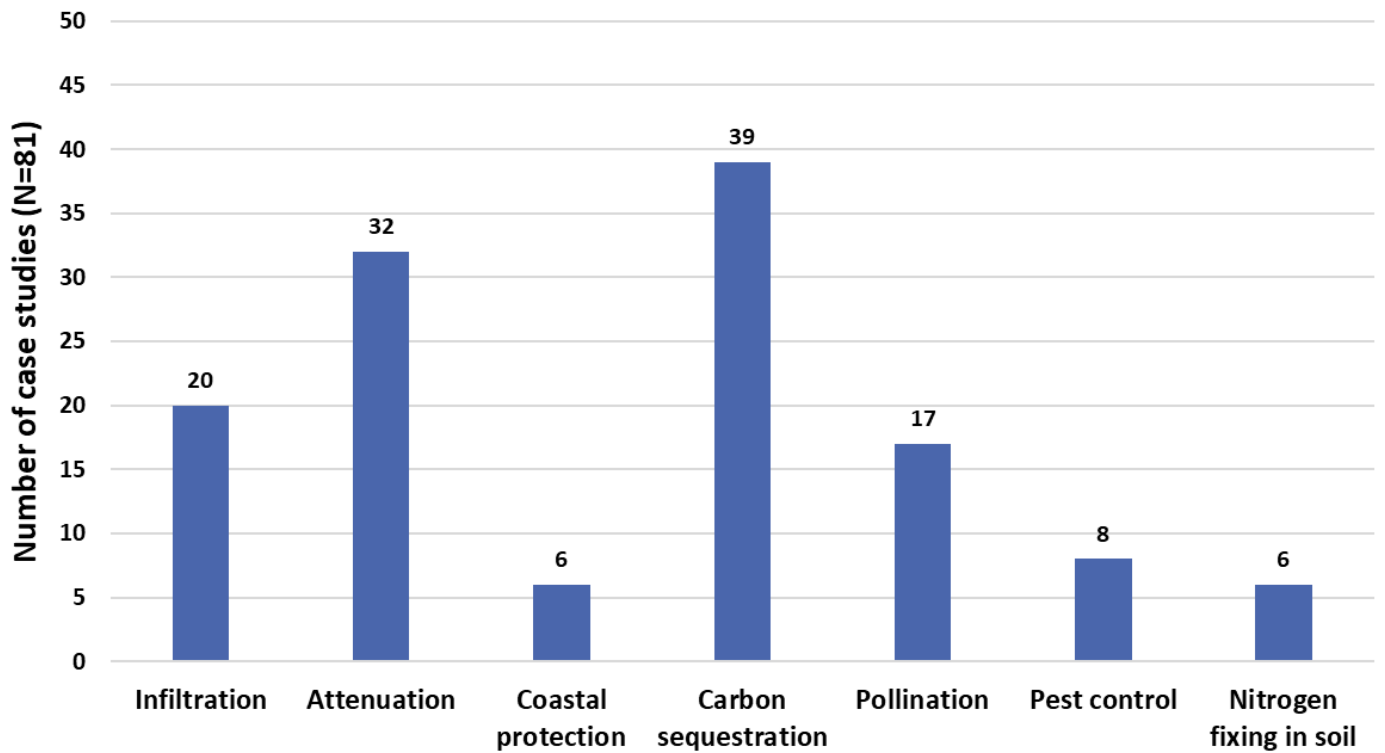


Figure 3. Ecosystem services delivered within the NBS examples. The data labels represent the number of project examples each ecosystem service was provided in, out of the 81 in total.

Ecosystem services provided by each nature-based solutions type

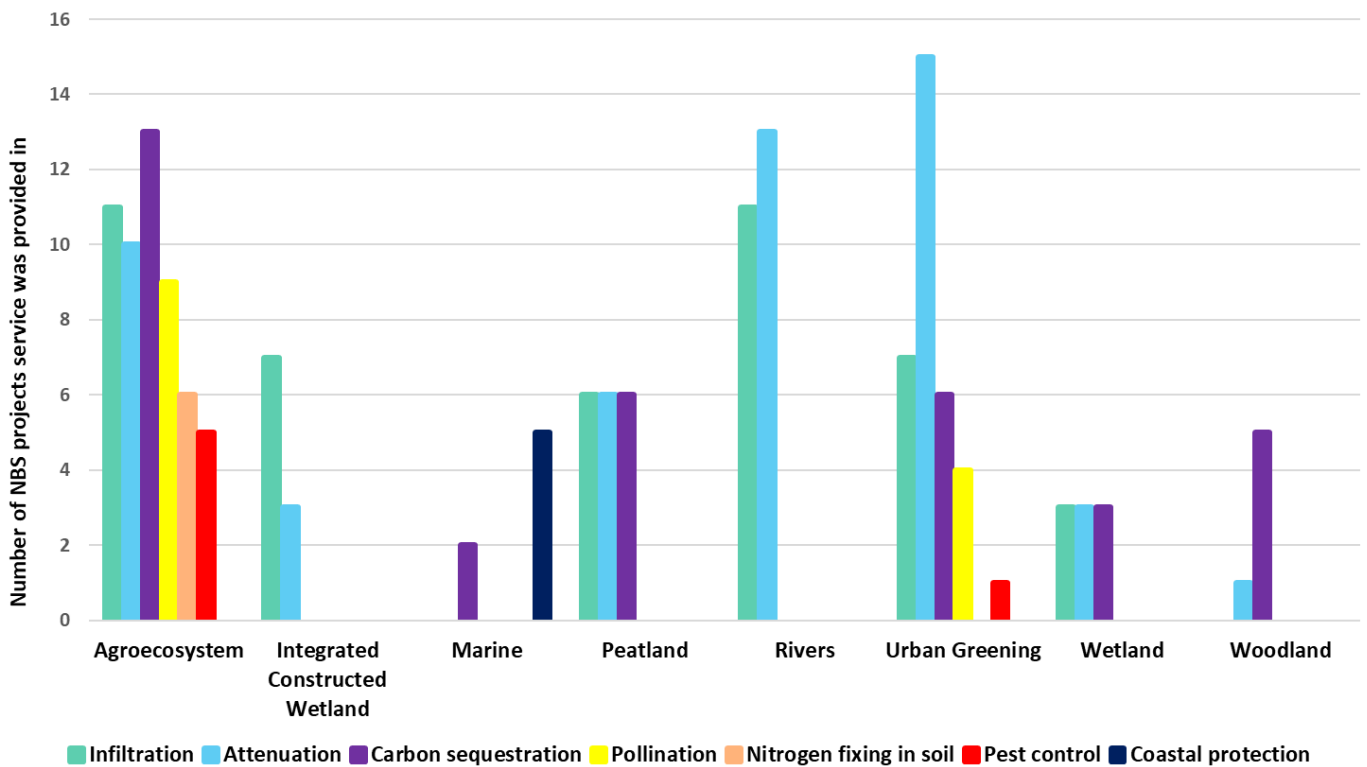


Figure 4. The ecosystem services provided by each nature-based solutions type identified within the study. These ecosystem services are self-identified by the authors of this report.

Results-based payments (RBPs) for NBS on agricultural land appear to offer the most economic co-benefits along with providing these benefits to a wider range of beneficiaries. While the RBP schemes themselves are not NBS as a number of actions can be completed for monetary award that are not nature-based solutions, some of the measures (i.e. ecosystem restoration, afforestation, addition of riparian buffers and attenuation ponds (**Figure 5.**)) implemented through these schemes can be NBS to climate issues. Receiving results-based payments allows farmers to input the payments back into the local economy, often to labourers who will carry out further NBS actions on their farms under the various RBP schemes. For example, farmers participating in the Burren LIFE project will often hire contractors from the area to undertake more labour-intensive tasks such as scrub clearance, which improves grassland habitats and therefore soil quality and land productivity⁶¹. The actions carried out under the Burren LIFE project also enhance biodiversity and associated services, improve the productivity of land and water quality, and protect the natural heritage and cultural significance of the Burren. These benefits have the potential to positively impact farmers, landowners, local communities and visitors to the area. Other RBP schemes such as the North Connemara Locally led Agri-Environmental Scheme EIP and the Pearl Mussel Project also benefit local economies by providing jobs in the locality, as these schemes have their project offices in the local area.

Nature-based solutions within agroecosystems

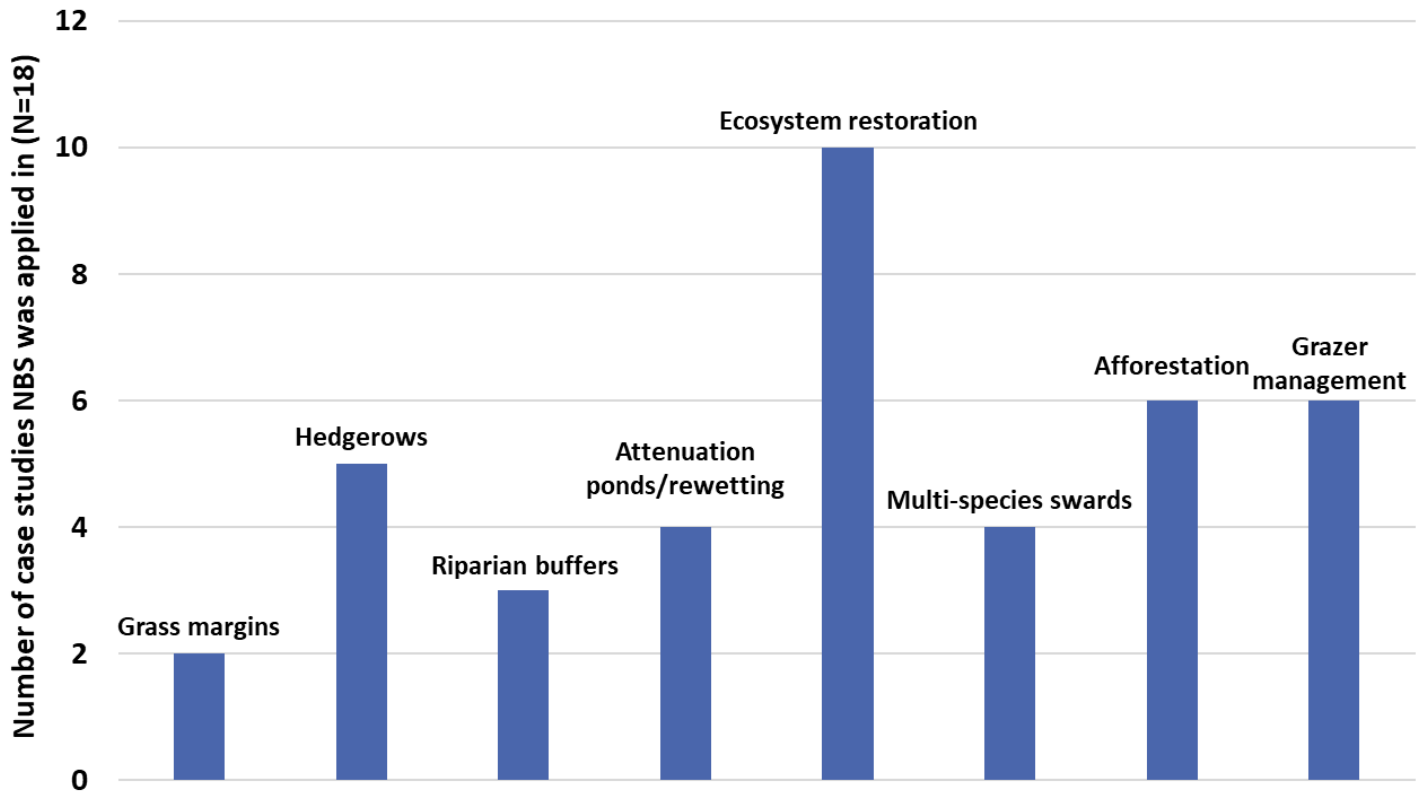


Figure 5. Nature-based solutions applied within agroecosystems[§].

NBS projects included in this study offer either mitigation or adaptation potential, or in some cases, both. Habitat restoration efforts, such as through peatland and woodland restoration, are principally undertaken to offer climate mitigation services. However, in restoring these habitats, adaptive services are restored simultaneously. For example, if a peatland is restored to store carbon from the atmosphere, it also has the potential to attenuate flood water and filter pollutants to improve water quality. While restored peatlands have the capacity to attenuate flood water, increased storage is limited in heavy rainfall events. However, they do have the ability to “slow the flow” of storm water into rivers, which can delay and reduce flood peaks⁶². Restoring ecosystems also enhances biodiversity to increase services such as pollination and pest control. Constructed wetlands also have a similar effect – they are usually implemented to treat wastewater, but they also have the ability to sequester carbon and reduce GHG emissions⁶³.

From literature and online databases, there is clearly more emphasis on the implementation, and a more successful implementation of flood management NBS (within this study, 35% of the NBS projects are related to flood management) such as attenuation ponds within urban areas that adapt to flood risk and improve runoff water quality. Attenuation ponds are an efficient way to attenuate stormwater runoff whilst also filtering pollutants to improve the quality of water entering our water bodies. These projects are implemented to both reduce flood risk while also improving the quality of our waterbodies. The use of flood management NBS are a useful measure, in appropriate locations,

[§] Grazer management represents both fencing watercourses to protect from livestock and the utilisation of traditional grazing regimes such as Winterage to enhance floral diversity.

to tackle the increased rainfall that we have been experiencing and are predicted to continue to experience⁶⁴.

Other solutions that will attenuate rainwater and reduce flooding are the use of rain box planters or “living walls”. These can provide multiple services, such as attenuating rain water, enhancing biodiversity, and reducing urban temperatures through shading⁶⁵ and evapotranspiration⁶⁶. Rain box planters have been piloted across Dublin city, and have proven to be an effective measure in attenuating rainwater, while also being popular with residents^{67,68}.

The NBS examples included in this study depict the wide range of actors that can undertake these measures. Individuals, Tidy Towns and other community groups, schools, farmers, local authorities and charity organisations are all examples of groups from the compendium, in Appendix 2, who have undertaken NBS projects. While measures have been implemented across sectors and personnel, there is no clear way in which many NBS are evaluated and monitored for their success and effectiveness (or ineffectiveness), and their future resilience to changing climatic conditions. The development of robust monitoring and evaluation frameworks will enable sectors to assess the strengths and weaknesses of specific NBS measures and interventions in achieving climate goals, understand benefits and trade-offs, and sustainably manage NBS in the long-term⁶⁹.

For the results-based payment schemes within the agricultural sector (e.g. Rural Environment Protection Scheme (REPS)), monitoring the environmental impacts of the measures undertaken is important for the long-term justification of expenditure on these and future schemes. A scoping study by Finn and Ó hUallacháin⁷⁰ 2012, found that there was an absence of comprehensive, national-scale monitoring of the environmental impacts associated with REPS. As a result, there is insufficient evidence with which to judge the impact of the NBS measures implemented through the scheme. Finn, 2010⁷¹ suggested various recommendations for monitoring the environmental impacts of REPS. These included recommendations such as “Monitoring effort should be preferentially directed at the measures that address the higher priority objectives”, “Monitoring effort should be preferentially directed at the measures that involve greatest expenditure”, and “The results of the monitoring programme should be reported as peer-reviewed journal articles. Sufficient project resources should be allocated to ensure this”. It was estimated that the environmental monitoring of selected REPS measures, supplementary measures, and biodiversity options would cost €3.4 million over a 4-year period, 0.25% of annual expenditure on REPS at that time (2010)⁷².

For the Green Low-Carbon Agri-Environment Scheme (GLAS), the successor of REPS, a monitoring and evaluation programme was implemented, representing the first time an Agri-Environmental Scheme (AES) has been assessed at a national scale across sample sites on a consistent basis⁷³. While having a monitoring and evaluation programme was a significant step for monitoring the effectiveness of environmental impacts, there are still some improvements to be made to this programme. Elliot et al. 2020⁷³ recommends reviewing this programme for the next AES, through establishing a baseline for sites (surveying sites before actions are implemented) and extending monitoring timeframes; incorporating a wider survey of mobile species, not only target species; and utilising ecological modelling to estimate effectiveness, especially in areas where data is difficult to gather. The Agri-Climate Rural Environment Scheme (ACRES), the successor to GLAS, has implemented an even stronger monitoring and evaluation system. A baseline is to be established with an ACRES advisor visiting the farm and taking photographs. They will also check the environment for suitability of various actions and options. Participating farmers must engage with an

approved ACRES advisor to prepare and submit an application, with a Farm Sustainability Plan forming part of this application. Along with these requirements, participants are required to attend training events in the first year of the scheme to facilitate knowledge transfer. These events will be complemented with online demonstrations and advice. The Farm Sustainability Plan will inform appropriate selection of actions, which are presented in a tiered structure and ranked by: Tier 1 (Natura and commonage lands, priority water areas, conservation of rare breeds), Tier 2 (vulnerable water areas), and Tier 3 (other actions from a list of General Actions that target local/farm specific environmental priorities)⁷⁴. Each action forms the scorecard which determines the amount each participant will receive each year. The aim of this approach is to achieve the underlying principle of this scheme, which is “the right measure in the right place”, to deliver the targeted and prioritised delivery of environmental benefits.

Integrated Constructed Wetlands (ICWs) implemented by Uisce Éireann have monitoring frameworks implemented, with information on the Tolka River Constructed Wetland stating that water monitoring is being carried out⁷⁵. The Castle Leslie Integrated Constructed Wetland has clear monitoring measures, with technology to record all flows into and within the wetland, automatic samplers, Lysimeters to indicate infiltration through the subsoil, and piezometers to allow groundwater in and around the wetland to be monitored⁷⁶. Failing of ICWs will be obvious, as water quality will decline. Other NBS measures may not be so obvious when they start to become less effective or fail, hence why a monitoring and evaluation framework should be in place for all implemented NBS.

Other NBS measures with monitoring programmes include the AfterLIFE plan, which aims to evaluate the impact of the Living Bog project, quantifying the success of peatland restoration from the sample sites and providing recommendations for future bog restoration efforts. This plan will monitor project sites and propose further actions to achieve favourable status; monitor the ecohydrological results in the years following the restoration works for a minimum of 5 years; and disseminate the results⁷⁷.

Apart from monitoring of ICWs and agricultural NBS measures, there is insufficient practical experience regarding monitoring, evaluating and maintaining NBS, especially within urban settings, or quantifying (including economic valuation) the benefits and co-benefits of their ecosystem services. This is proving to be an obstacle in the uptake of NBS by decision-makers, who do not have the resources to address challenges using optimal solutions⁷⁸. Lack of knowledge and limited data available suggest that the socio-economic aspect may also be a significant barrier to the implementation of NBS in Ireland, along with the lack of collaboration across departments and reliance on traditional funding channels and approaches²².

Financing of nature-based solutions

The NBS included here are representative of measures implemented across sectors, land uses and ecosystems. They include self-funded, local authority, governmental and European funded projects. While NBS have the capacity to be undertaken on a completely self-funded and voluntary basis, there are many funding opportunities within Ireland and Europe to implement NBS within communities, organisations, or on private/agricultural land:

- Climate Action Fund⁷⁹ was established to fund projects which will assist Ireland in achieving its climate and energy targets through innovative initiatives which may not be possible to accomplish without this support. Funding is being provided to local authorities to build low carbon communities in a structured way, and is also being provided to build community capacity in relation to climate action.
- Community Environment Action Fund⁸⁰ promotes sustainable development by supporting local level, small-scale projects. Local authorities co-fund successful projects with the Department of the Environment, Climate and Communications, with communities and local groups working with local authorities to take action on waste, biodiversity, climate change, and water. Funding within this initiative can also come from other sources, like the private sector, to make projects more successful.
- Community Water Development Fund⁸¹ is provided by the Local Authorities Waters Programme (LAWPRO), which receives funding from the Department of Housing, Local Government, and Heritage to support this initiative. This fund assists community groups to enhance the quality of local streams, rivers, lakes and coastal areas. Actions can include river and habitat enhancement, and biodiversity action plans.
- Department of Agriculture, Food and the Marine (DAFM) Forestry Programme 2023 – 2027⁸² will fund farmers, landowners, etc., to undertake various interventions, such as agroforestry, forest creation, climate resilient reforestation and sustainable forest management.
- Results-based payment schemes that farmers and landowners can participate in, whereby they receive payment for implementing NBS measures under the Common Agricultural Policy (CAP) scheme. In Appendix 2, the ACRES scheme comes under CAP, along with other schemes such as Eco-scheme⁸³, which rewards farmers for undertaking actions beneficial to climate, environment, water quality, and biodiversity.
- Further results-based payment schemes are offered that are not under the CAP scheme. These can include habitat restoration and biodiversity enhancement projects, such as the Pearl Mussel Project. This project offers payments to farmers who deliver environmental benefits that improve water quality and the river habitat for the pearl mussel. It is funded by DAFM and is a European Innovation Partnership (EIP) Scheme. Other projects that offer results-based payments to farmers who action ecological and sustainable benefits on their land include the LIFE programmes, which provides funding for the support of nature conservation, the environment, and climate action throughout the EU⁸⁴.
- EU Just Transition Fund is for assisting the most affected regions in transitioning to a climate neutral economy. This could include up- and reskilling of workers, investments in small and medium sized enterprises, research and innovation, and environmental rehabilitation⁸⁵.
- Horizon Europe is the EU's key funding programme, supporting research and innovation projects that tackle climate change and help achieve the UN's Sustainable Development Goals⁸⁶.

The compiled list of NBS in Appendix 2 receive funding from the various aforementioned avenues. The Irish government has provided funding for a myriad of NBS projects, including for the projects within the Rivers Trusts' charity, while also co-funding many of the projects with local authorities, including the Monaghan Wetland Action Plan. Projects can be funded under the above schemes, or they can support the action plans and frameworks mentioned in the Introduction.

Discussion

The compiled table in Appendix 2 represents a non-exhaustive catalogue of NBS in Ireland. These NBS have been recognised as successful measures to tackle specific climate issues, which will aid in the provision of valuable ecosystem services, reducing the impacts of climate change and biodiversity loss, while also enhancing job creation, human well-being, and social inclusion. As mentioned, 81 different NBS projects/case studies were identified through this study, highlighting that there are many small, localised NBS being implemented across the country, although many are not defined as such.

Barriers of implementing nature-based solutions

NBS have a multi-functional role, which allows them to have great potential to tackle climate, environmental, social, and economic challenges⁸⁷. While it is obvious that **NBS are an effective measure in tackling global challenges**, there are many barriers to their implementation. **Funding is a major barrier** to implementing NBS, with funding schemes preferring short-term projects, when the co-benefits of NBS are mostly realised over long-term periods⁸⁸. **Governmental bodies and local authorities have limited resources**, and solely relying on them to fund NBS projects places immense pressure on these institutions. The economic benefits and creation of jobs through NBS projects needs to be highlighted in order to attract more funding⁸⁹. **Another barrier to the implementation of NBS is the experience and opinions of the decision makers**. They may be accustomed to utilising “grey” infrastructure to solve issues and enhance built-up areas to increase economic growth, and therefore may be resistant to change⁹⁰. This is **also perhaps a failing of the academic field, as has been mentioned, there is insufficient published data and evidence of NBS in Ireland** in which to base decisions off, as well as a lack of collaboration across sectors to share knowledge. **Lack of information or uncertainty about NBS benefits and implementation process**, which can also be related to the previous barrier, is another limiting factor in the implementation of NBS. There is a somewhat lack of comprehensive information regarding the implementation and management of NBS, coupled with multiple uncertainties due to the fact that they can be applied across complex social-ecological systems⁹¹. **NBS data mostly exists within academic literature, with little trickle down into the general public**⁹² – providing more information to communities and local authorities detailing NBS implementation, effectiveness and management may improve acceptance and utilisation of these measures.

Considerations for applying nature-based solutions

Land-use or sea-use change from applying certain NBS is another issue which must be considered before implementation. Gorman et al. 2023⁹³ discuss the potential impacts that climate action measures may have on biodiversity in Ireland. Current **afforestation schemes plan to use non-native monocultures of coniferous trees to mitigate climate change**, such as Sitka Spruce (*Picea sitchensis*), which provide limited value to biodiversity. When planted on high nature value areas such as semi-natural grasslands or peatlands, these **monocultures cause negative impacts to the ecosystem and associated distinctive species**. Gorman et al. recommend instead using a mix of native species with a balance of commercial monocultures, as they will host more biodiversity and will be more resilient to pests, but note that the greatest positive impact on biodiversity would occur if only a mix of native trees were used. Forster et al. 2021⁹⁴ found that commercial forestry in temperate regions mitigates more CO₂ over a 100-year period than planting only conservation forests, depending on species composition. This study only took climate mitigation measures into account, and did not look into how this would impact biodiversity and other ecosystem services.

Therefore, to enhance both biodiversity and carbon mitigation, **a balance of commercial forestry and mixed native tree forests would indeed be the most effective climate action measure.** Where non-native monocultures are planted must firstly be considered, and **high nature value areas should be avoided in order to conserve these sensitive habitats and associated species.**

Considering what species to utilise must also be taken into account **for urban greening** to reduce local temperatures, attenuate rainwater, enhance biodiversity and improve water quality and human wellbeing. The functional traits and biogeographical distribution of a species must be considered when creating urban green areas²⁷, **otherwise it may lead to poor resistance to climatic events, increased management costs and risk of biological invasion.**

It is clear that many NBS have been implemented throughout Ireland and across land-uses and ecosystems. **Multi-sectoral and disciplinary teams play a huge part in the successful undertaking of a NBS project.** The Maharees, Co. Kerry, show that community collaboration is a significant tool in the maintenance of the dune restoration and protection NBS that have been implemented, however the inclusion of other sectors would allow them to move forward with more permanent solutions. The Maharees Conservation Association have acknowledged its successes in responding to immediate issues since forming in 2016, but no permanent solutions have been identified. Community collaboration will continue to maintain their current efforts. However, unless actions to co-design and implement sustainable, integrated and enforceable coastal management to the peninsula are facilitated, socio-economic and environmental resilience of the Maharees is unlikely to be sustainable⁹⁵.

Collaboration is vital to maintain nature-based solution measures, as was also highlighted in "The Case Study of Maghery, Co. Donegal"⁹⁶. This Special Area of Conservation (SAC) faces shoreline erosion due to storm surges and sediment supply to the system⁹⁷. A collaboration between Donegal County Council, local residents and NGOs, built a sand-trapping system comprised of wooden support poles placed 11 m from the face of the dune system and onto the beach. This solution successfully led to the regeneration of the dune system and increased sand levels from 2006 to 2011. However, after 2011, higher levels of erosion became evident – this was due to severe winter storms and a failure of the collaborators to maintain the sand trapping system. This highlighted that **roles must be formally assigned to stakeholders in order to maintain these solutions, with regular communication between all stakeholders, and the assurance that all participants understand their roles.** The sand trapping system was reimplemented in 2015.

These two case studies underline the **importance of effective communication and management before, during, and after the implementation of a NBS measure.** Current **monitoring and evaluation** processes rely on resource availability (time, budget, personnel) which isn't often accounted for in the initial budget of a NBS project⁹⁸, therefore there is a need for a more effective technique. **Satellite remote sensing could be a useful tool to monitor the performance of NBS to mitigate climate change**⁶. Further research into this area could highlight the benefits and effectiveness of NBS to solve climate challenges, improving acceptance of these measures among decision makers and the general public. **Employing personnel on the ground to monitor and evaluate NBS would also be an effective measure** and would contribute to local economies through job creation.

Natural Capital Accounting (NCA) should also be considered when monitoring and evaluating NBS measures. NCA measures the benefits ecosystem services provide to us⁹⁹, therefore **the multiple benefits of a NBS measure could be captured through this method.** ForES¹⁰⁰ is developing technology to assess the quantity, quality and location of forest stocks, while also determining carbon sequestration, water retention, biodiversity and recreation benefits. Farm Zero C¹⁰¹ are also developing NCA technology to measure the effectiveness of NBS in agriculture. These technologies are being developed at site level, where most NBS are being implemented, and are an example of research being effectively translated into practice. **The quantifying of NBS ecosystem services through NCA is also useful for informing policy, as it shows the ecosystem's contributions to the economy, society, and the environment**^{102,103}.

Currently, **climate action targets in Ireland are expressed as national objectives, while delivery must happen at regional or local levels.** There are many challenges faced by governmental and local level institutions to downscale these targets and deliver them at a local scale. More must be done to understand how to effectively action NBS across sectors. **A climate neutral and resilient economy must be delivered in a fair and just transition,** the costs shared impartially, with climate policies protecting and supporting the most vulnerable in Irish society, and those who will be negatively impacted by this transition¹⁰⁴. A just transition has the potential to create new jobs, opportunities, and skills, along with creating a more resilient economy. The UN Environment Programme (UNEP) stated that investing in NBS could create up to 20 million new jobs, particularly in rural areas that require a just transition away from the unsustainable use of nature¹⁰⁵. In Ireland, Bord na Móna have announced that 1400 new climate solutions jobs will be delivered over the coming years¹⁰⁶.

Progress on NBS solutions for climate adaptation and mitigation across sectors is limited, apart from flood risk and water quality projects, where progress is good⁹⁸. This highlights that the current benefits of NBS appear to be limited to urban areas that are threatened by flooding. Utilising NBS to reduce flood risk is a cost effective solution (but not always the only/most effective solution), and there is more information on flood adaptation NBS provided by the Government of Ireland than other NBS, for example: Nature-based Solutions to the Management of Rainwater and Surface Water Runoff in Urban Areas³¹, and Nature-based Solutions for Catchment Management³². There are also significantly more flood risk and water quality based NBS implemented than any other NBS, with many implemented across the country.

One of the **main challenges of implementing NBS is the lack of knowledge transfer.** Best and Hochstrasse, 2022⁹⁸ interviewed personnel from across sectors, who shared their opinions on the challenges of implementing NBS in Ireland. Interviewees suggested that a panel of ecologists who can directly inform and aid farmers in implementing appropriate NBS would be an effective measure in providing more information to farmers, improve support of NBS, and distribute the benefits of NBS to more sectors of society. ASSAP (Agricultural Sustainability Support and Advisory Programme) was implemented in 2018¹⁰⁷, which is a sectoral wide advisory service to help inform farmers about what measures can be implemented to improve water quality¹⁰⁸. **Integrating NBS implementation and monitoring into the training of advisors in programmes like ASSAP, while also rolling out more advisory programmes across sectors, would be an effective tool in scaling up the use of NBS at a national level. More toolkits and guidance documents must be prepared to offer direction on the implementation, benefits, and management of NBS,** so that they can be utilised by all sectors of society across the variety of land uses and ecosystems. **To improve knowledge transfer, a**

comprehensive, freely available database of NBS in Ireland, with: evidence of their benefits (social, economic, environmental) within different land uses and ecosystems; evaluation frameworks to assess their performance across mitigation, adaptation, water dimensions and biodiversity; and implementation measures, representing both effective and ineffective would also be useful. The Conservation Evidence database method described by Sutherland and Wordley, 2018¹⁰⁹ is a good example of how to provide evidence from multiple sources on specific topics, in a free, easily navigable approach. Following this method, measures to implement NBS, or to understand their benefits, services provided, and beneficiaries etc., would be collected from published articles, online reports, or unpublished material from local authorities and NGOs. Experts would review publications and evaluate the effectiveness of the NBS measures. Publications would be uploaded, once evaluated by the experts, onto the database under relevant topic headings, making them easy to find and comprehensible by non-scientists. This would create a central NBS database in Ireland where decision-makers, stakeholders, communities, landowners, etc. could go to, to search for appropriate NBS for their particular issue, understand the benefits, and find comprehensive implementation measures. A permanent database of all NBS measures implemented across Ireland would also be a practical source for stakeholders who are looking to implement NBS. This database could be searched for specific NBS types, or what problem is to be solved, and users can view what measures have been effectively implemented in Ireland, along with what services and co-benefits they provide.

NBS in Ireland are implemented throughout the various ecosystems and land uses to date. However, there is **more focus on the restoration of degraded ecosystems such as woodlands and peatlands to mitigate climate change, rather than the protection of what already exist**. Restoration of these carbon sinks will mitigate GHGs as these habitats become functional, which may take some time, compared to protecting what we have now which will assist in already occurring mitigation. Increased protected areas and nature reserves designated across the island would, if appropriately managed, aid both climate adaptation and mitigation, provide multiple co-benefits, and enable achievement of a carbon neutral climate while protecting priority habitats and species.

So far, **many successful NBS have been implemented nationwide to reverse biodiversity loss and increase climate resilience**. However, the implementation of NBS to create a more sustainable and resilient environment and economy is not happening at a quick enough pace and large enough scale. There is a **need for more collaboration across sectors, and more engagement from NGOs, local authorities, and the private sector in the planning and implementation of NBS**. Coherence across frameworks, action plans, and policies to implement climate mitigation and adaptation strategies is essential¹¹⁰, along with highlighting the importance of an all-island approach to a carbon neutral climate.

Conclusion

NBS have been identified as an effective measure in reducing the impacts of climate change and biodiversity loss. Three key principles for the successful implementation of NBS were identified by Cohen-Shacham et al. 2019¹¹¹. These include:

- NBS can be implemented alone or integrated with other solutions (e.g. technological and engineering);

- They should be applied at a landscape scale – even when an NBS is implemented at site level, the wider landscape and ecosystem contexts should be considered; and
- NBS are fundamental to the overall design of policies and actions that address societal challenges. They should not only be practically undertaken in the field, but also incorporated into policy and related actions and frameworks.

Monitoring and evaluation of implemented NBS is necessary, considering the dynamic characteristics of nature as a solution. Changing climatic conditions due to global warming will impact the solutions implemented, therefore it is important that there are appropriate monitoring frameworks in place. All elements of our environment are connected, so there must be appropriate consideration for how NBS will impact all ecosystems in the wider landscape, while also considering how they will impact society and the economy.

Having an advisory committee or central governmental unit on NBS would encourage the creation of certification and standards to which NBS can be implemented and actioned, ensuring that the appropriate solution is being actioned with no negative impacts to the surrounding environment. Natural Capital Accounting would be an asset in this area, as it would give an idea of how NBS are performing, while also showing the co-benefits produced. Monitoring NBS would also help us understand if they are producing any unintended consequences, and assist the improvement of implementation going forward, and how these consequences can be rectified.

The planning, implementation and monitoring of NBS should be integrated into advisory programmes, such as the ASSAP, LAWPRO Community Officers and advisory services provided through the ACRES programme. These programmes could engage with anyone looking to solve issues using NBS and advisors should be trained in the implementation and monitoring of NBS to ensure environmental targets are being delivered.

The purpose, context, and location must be considered when deciding to implement a NBS. A NBS may not always be the most appropriate solution, or may need to be implemented along with technology or grey infrastructure. The long-term maintenance of NBS and the surrounding landscape also needs to be addressed, with upskilling across sectors (especially engineers, planners, local authority employees) in the design, implementation, and maintenance of NBS.

A collaborative approach between all governmental departments and key infrastructure agencies is essential for streamlining NBS in Ireland, along with active engagement with local communities in the planning process, with clear explanations of the benefits and co-benefits provided by NBS³¹. Policy responses which integrate NBS must also be coherent across sectors and inclusive of affected communities⁹⁵.

A comprehensive and shared definition for NBS for policymakers across sectors would also be beneficial – while it is not important to get into an approved definition, a shared understanding of what makes an action a NBS will allow for more effective monitoring and evaluation frameworks to be implemented, as it will be clear as what constitutes as NBS, their outcomes, and co-benefits. A shared understanding will allow for more collaboration across sectors and encourage the integration of NBS into local and sectoral plans. Responsibility for NBS cuts across multiple government departments and agencies so will either require a dedicated cross-departmental unit or assignment to an existing unit with a mandate to work across government departments/agencies/units.

While NBS have the ability to reduce emissions and mitigate against climate change, and adapt our ecosystems and land uses to future extreme weather events, they are not an excuse to continue emitting greenhouse gases. NBS must be implemented along with decarbonisation across all sectors. As highlighted, published literature of NBS in Ireland is limited, therefore more research into understanding what is already implemented and how effective the solutions are is required.

Encouraging private building owners who have implemented urban greening actions such as living walls and living roofs to register their NBS project would allow for a greater idea of localised climate adaptation and mitigation measures. Understanding how various NBS projects are impacting the surrounding landscape is also important, along with understanding the Irish public's opinion on the use of NBS as practical solutions to climate issues. Further research into the complete area covered by current NBS projects would also be beneficial. This would highlight the progress of NBS in Ireland, and give an idea of how much further it is needed to go with the implementation of NBS for climate mitigation and adaptation. A complete compendium of NBS in Ireland (including those not defined in literature as "nature-based solutions") would also be important future work to convey to stakeholders and the Irish general public the variety of NBS that exist already, and that can be applied to various landscapes.

Appendices

Appendix 1 Workshop attendees

Attendees at the workshop, hosted in the Zoology Building, Trinity College, Dublin 05/09/2023,
14:00 – 16:00

- Aoife Molloy, Trinity College Dublin
- Yvonne Buckley, Trinity College Dublin
- Marcus Collier, Trinity College Dublin
- Cian White, Trinity College Dublin
- Iris Möller, Trinity College Dublin
- Brian Murphy, Department of Agriculture, Food and the Marine
- John Mounsey, Department of Agriculture, Food and the Marine
- Conor Galvin, Office of Public Works
- Mark Adamson, Office of Public Works
- Bryn Canniffe (online), secretariat to Climate Change Advisory Council

Appendix 2 Compendium of nature-based solution projects in Ireland

Link to compendium of NBS projects:

<https://doi.org/10.5281/zenodo.10246547>

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