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# Assessment Of Biodiversity Considerations in the Carbon Budgets Process

Authors: Molloy, A., Jarmain, C., Byrne, K. A., Daly, H., Emmerson, M., McKeon, C., Moran, J., Moriarty, R., Styles, D., Buckley, Y. M.

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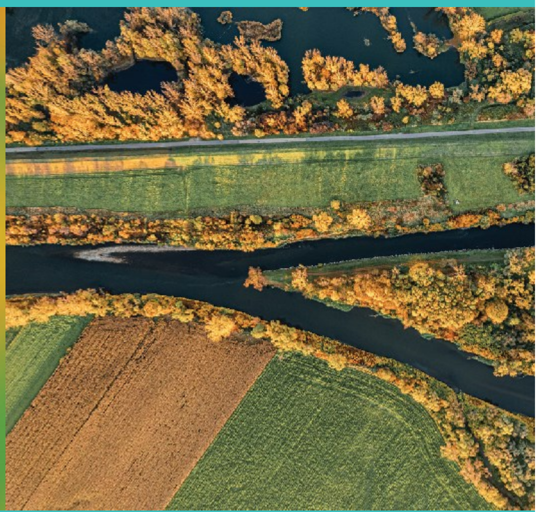
# Assessment Of Biodiversity Considerations in the Carbon Budgets Process





**Aoife Molloy**, Trinity College Dublin

**Caren Jarmain**, Trinity College Dublin; University of Stellenbosch, South Africa

**Kenneth A. Byrne**, University of Limerick; Co-Centre for Climate + Biodiversity + Water

**Hannah Daly**, University College Cork

**Mark Emmerson**, Queen's University, Belfast; Co-Centre for Climate + Biodiversity + Water

**Caroline McKeon**, Trinity College Dublin, Co-Centre for Climate + Biodiversity + Water

**James Moran**, Atlantic Technological University

**Róisín Moriarty**, University College Cork

**David Styles**, University of Galway

**Yvonne M. Buckley**, Trinity College Dublin, Co-Centre for Climate + Biodiversity + Water

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Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

Universiteit Stellenbosch University 100 1918-2018

University of Limerick
Ollscoil Luimnigh

Queen's University Belfast

Ollscoil Teicneolaíochta an Atlantaigh
Atlantic Technological University

UCC
University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

Ollscoil na Gaillimhe
University of Galway

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Illustrations of Irish land uses providing different levels of biodiversity, GHG emissions and climate change mitigation services. Photo credits C. Jarmain, Y. Buckley, A. Molloy and Coillte (energy generation: https://www.coillte.ie/irelands-largest-wind-farm-enters-commercial-operation)

# Non-technical summary

For Ireland to achieve its ambitious carbon budget targets to reduce greenhouse gas emissions, significant changes of land and sea use are necessary over the coming years. The required changes, particularly in the agriculture, energy and forestry sectors, will have implications for the health and condition of habitats and the spatial distribution of species. This report was developed to address the need to consider impacts to biodiversity in achieving the carbon budgets targets and to make recommendations on how best to incorporate biodiversity in this process.

The report outlines the main policy frameworks for climate action and biodiversity protection and restoration in Ireland. An analysis of trade-offs, synergies and lose-lose scenarios is provided for climate and biodiversity actions mandated by the different policy frameworks. This analysis is provided for different land use categories as a basis for assessing risks and to identify appropriate risk mitigation measures.

The report emphasizes the need to achieve statutory obligations for biodiversity protection and restoration and align policies and targets for both climate and biodiversity. It calls for the development of a national integrated land use strategy to inform on the ground actions and for this strategy to be underpinned by a spatial planning framework as impacts on biodiversity are highly context and location specific.

The report highlights the importance of the increased adoption of nature-friendly forestry and farming practices and the appropriate siting of renewable energy infrastructures in achieving land use change for climate and biodiversity benefits. The report also identifies the need to define the meaning of the climate neutrality and biodiversity rich aspects of the national climate objective. Lastly, it states that Ireland should avoid contributing to biodiversity and carbon decline in other countries.

# Executive summary

Climate change and biodiversity loss are interconnected global crises and must be addressed together. Climate change exacerbates biodiversity loss, and the loss of biodiversity weakens ecosystems' resilience to climate change, reducing their ability to provide ecosystem services essential for the economy, society and human health and wellbeing. Ireland's contribution to global environmental crises is significantly influenced by its import and export activities. The country's reliance on imported energy and goods, combined with national patterns of resource consumption, waste production, and energy demand, plays a critical role. Additionally, agricultural exports, particularly beef and dairy, contribute to greenhouse gas emissions and likely deforestation (where supported by imported feed), further exacerbating these challenges.

By law, Ireland is required to achieve climate neutrality and a "biodiversity-rich" state by 2050 under the National Climate Objective. However, policies to address these two crises are not fully aligned across sectors, and the impacts of climate mitigation measures for carbon emissions reduction on biodiversity are not assessed systematically. The annual carbon budgeting process for Ireland considers biodiversity impacts using an *ad hoc* process that does not systematically address the spatial context of biodiversity. To achieve the ambitious carbon budget targets, land and sea use will change, and this will have implications for the spatial distribution of biodiversity and how ecosystems function to deliver ecosystem services. This working paper addresses the need to consider biodiversity impacts in the carbon budget process and make recommendations on how to incorporate biodiversity into this process.

Two online workshops were held with a working group with expertise in the carbon budgets process and land use, energy, biodiversity, forestry and high nature value agriculture sectors. A webinar on biodiversity and carbon budgets was held with input from six international experts in Finland and New Zealand. Recommendations from both workshops and the webinar, along with reviews of published literature, were used to complete the final working paper.

A provisional, expert-informed, analysis of trade-offs, synergies and lose-lose scenarios for climate and biodiversity actions in different land-use/land-cover categories is provided that can be used to assess risks and identify mitigation strategies.

This study concludes that to achieve emission reduction targets whilst protecting biodiversity, Ireland will need to reach compromises involving demand management and resource use. Key recommendations identified through this study include:

- Statutory obligations for biodiversity protection and restoration must be implemented, with co-benefits for the protection of carbon stocks, reduction of greenhouse gas emissions and carbon removals through biological sequestration quantified. Policies which deal with land use should be aligned to achieve climate and biodiversity obligations.
- National land use strategy should be developed that explicitly considers climate actions, biodiversity protection and restoration as land uses and the land use strategy needs to align with climate and biodiversity obligations. The national land use strategy must be underpinned by regularly updated spatial data sources and include a spatial planning framework.
- Changes in land use practices are needed in the forestry, agriculture and energy sectors to achieve climate and biodiversity benefits through nature-friendly forestry and farming practices and appropriate siting of renewable energy infrastructures. Additionally, systemic change is needed for individuals, businesses, industry, and society as a whole, to reduce energy and resource consumption, and to minimise waste.
- Definitions of "climate neutrality" and "biodiversity-rich" are needed for the development of appropriate land use strategies and to better account for biodiversity and biodiversity change.
- Increased knowledge generation and sharing are needed to resolve key uncertainties, assess the impacts of actions and policies, and continually update climate and biodiversity actions in response to data.
- International impacts of climate and biodiversity action need to be assessed to avoid "off-shoring" climate and biodiversity impact. Ireland should not contribute to biodiversity and carbon decline here or elsewhere through resource exports or imports.

Addressing climate change and biodiversity loss requires integrated policies that consider their interconnected impacts. To achieve our carbon budget targets and climate neutrality, along with a "biodiversity-rich" state, biodiversity needs to be incorporated into the carbon budget process using a spatial framework, and biodiversity and climate action policies need to be aligned. The recommendations offer a framework to align biodiversity and climate change goals.

# 1 Introduction

Climate change and biodiversity change and loss are two of the most pressing concerns of our time (Pörtner *et al.* 2023) and these crises are interconnected (IPBES *et al.* 2021; IPCC 2023; Murphy *et al.* 2023; Pörtner *et al.* 2021a).

- Climate structures the distribution of biodiversity on Earth and climate change has a profound impact on biodiversity, with this impact likely to rise substantially under future scenarios (Scheffers *et al.* 2016).
- In turn, biodiversity change reduces the capacity of ecosystems to regulate the climate, reduces the ability of ecosystems to adapt to the consequences of climate change and alters the ecosystem services provided to people.

There are shared drivers of biodiversity change and loss, climate change (pollution and land and sea use change) and shared solutions (Figure 1-1). These include protecting carbon (C) stores in existing ecosystems, reducing greenhouse gas (GHG) emissions from land and sequestering carbon from the atmosphere in biomass, soils and sediments. Actions implemented to benefit biodiversity may support climate action, and measures implemented for climate action may support biodiversity. However, there can also be trade-offs, where actions positive for climate or biodiversity, have negative impacts on the other (IAP 2021) and in some ecosystems climate actions can be bad for both climate and biodiversity (lose-lose scenarios such as afforestation on peat soils). Whitmarsh *et al.* (2021) concluded that to address the climate crisis the focus should be on high-impact behaviours (transport, food, consumption, resilience) and high-emitting groups through interdisciplinary interventions that consider diverse behavioural barriers, people's multiple roles, and the timing when habits are weaker. Hence, a systemic change is needed for society as a whole to reduce energy and resource consumption and minimise waste.

Dáil Éireann declared a climate and biodiversity emergency in 2019, and put in place legislation, policies and action plans to address both crises, including reference to achieving a “biodiversity-rich” state in the national climate objective. Successive annual reviews of the Climate Change Advisory Council (CCAC 2017, 2018, 2019, 2020, 2021a, 2022, 2023) have progressively included references to biodiversity - from no mention of biodiversity in 2017, to 115 mentions of biodiversity in 2023 (Figure 1-2).

Policies addressing the climate and biodiversity crises are not yet fully aligned across sectors. The annual carbon budgeting process for Ireland does not systematically consider biodiversity; the assessment of biodiversity impacts of carbon budget scenarios is *ad hoc* (e.g. Gorman *et al.* 2022). The Climate Change Advisory Council annual review (2023) states

"*Potential synergies and conflicts between biodiversity and the other elements of the National Climate Objective have received limited attention and need to be further explored*" (CCAC 2023).

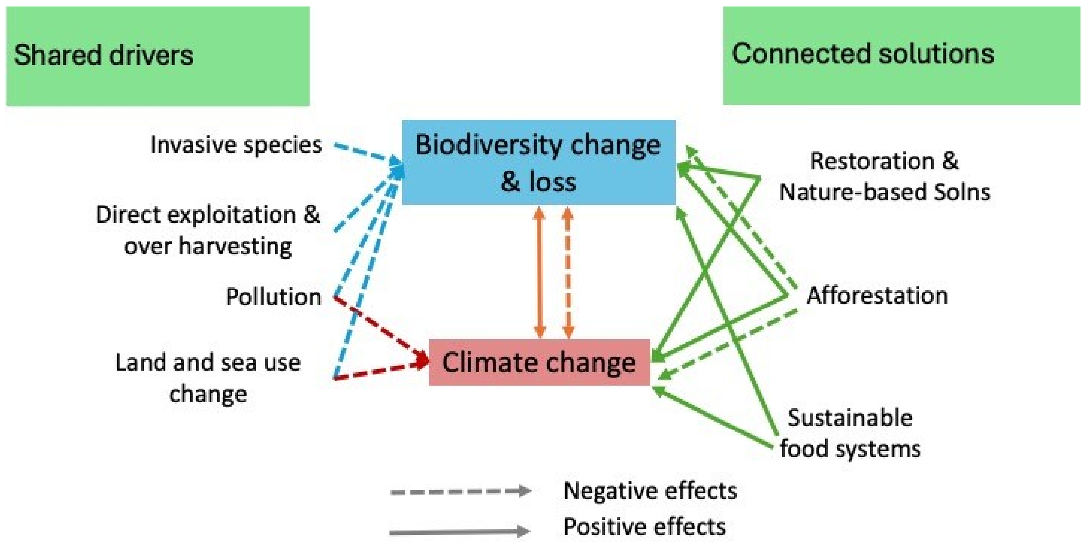


*Figure 1-1 Shared drivers of biodiversity loss and climate change, along with solutions that address both crises, demonstrating important interconnections between the two challenges. Solutions are positive or negative, depending on the context. E.g. afforestation is positive for biodiversity and climate if the right trees are planted at the right places to support habitats for a diversity of species and sequester C. Afforestation is negative for biodiversity when monocultures are planted on diverse habitats and managed so that it excludes or damages biodiversity, and negative for the climate when planted on carbon-rich soils and carbon is released due to disturbances and drainage.*

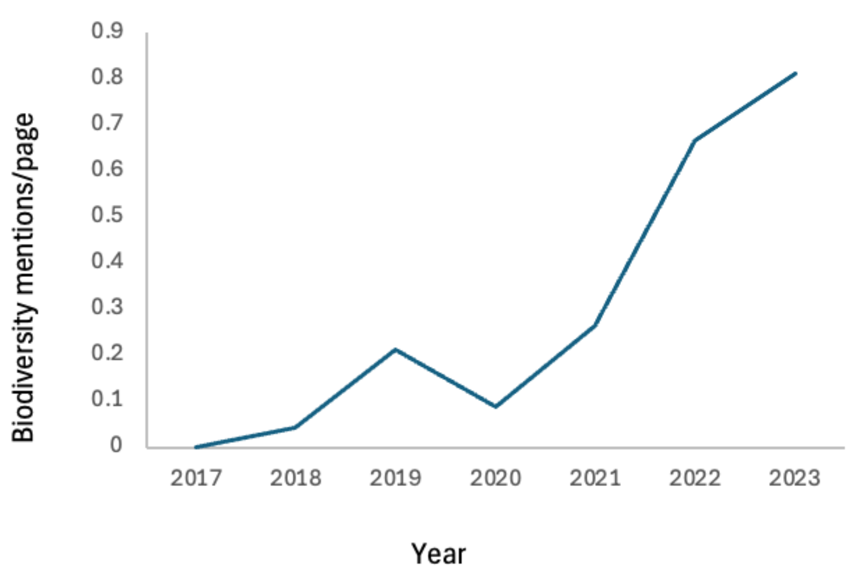


*Figure 1-2 Mentions of biodiversity per page in the CCAC annual reviews 2017 – 2023 demonstrating the increasing incorporation of biodiversity considerations into the Council's recommendations.*

The National Climate Objective (DECC 2022) commits Ireland to become a climate-resilient, biodiversity-rich, environmentally sustainable and climate-neutral economy no later than 2050 – which requires high-impact changes. Also, the recently adopted Nature Restoration Law sets legally binding EU nature restoration targets to restore degraded ecosystems, in particular those with the most potential to capture and store carbon, and to prevent and reduce the impact of natural disasters (EU 2024). It is therefore important to align climate and biodiversity policies: inappropriately addressing one challenge may have detrimental consequences on the other, leading to a failure to achieve the national climate objective and comply with the nature restoration law or achieve maximum synergies for climate and biodiversity.

Previous work provided recommendations for addressing climate change and biodiversity loss as general principles (e.g. InterAcademy Partnership statement on climate change and biodiversity loss (IAP 2021)), or recommendations for synergistic actions to be followed in different sectors in Ireland (Gorman *et al*. 2022) (Table 1-1).

*Table 1-1 Recommendations from the Inter Academy statement on climate change and biodiversity loss (2021) and aligned recommendations from Gorman* et al. *(2022) for Ireland.*

| **Inter Academy Partnership** | **Gorman *et al*. (2022)** |
|---|---|
| Build a sustainable food system with climate- and biodiversity-friendly agricultural practices, responsible food trade, and equitable food distribution; | Promote agroforestry |
| Reduce rates of natural ecosystem loss and degradation, protect, restore and expand natural ecosystems, and increase landscape connectivity; | Restore carbon-rich ecosystems |
| Ensure that the expansion of renewable energy systems has positive biodiversity benefits built into its design; | Integrate solar into the built environment<br>Increase offshore wind capacity |
| Recognise, respect and safeguard the rights and livelihoods of local and traditional users of ecosystems when implementing biodiversity and climate change actions; and | |
| Discourage ecosystem-based approaches to climate mitigation that have negative outcomes for biodiversity, such as tree planting in inappropriate ecosystems, monocultures, and unsustainable energy crops. | Afforestation with native trees |
| | Use of natural capital accounting (ecosystem accounting) |

To reach ambitious carbon budget targets and climate neutrality by 2050, Irish land and sea use will need to change: including agricultural diversification, carbon-rich habitats protected and restored, afforestation increased, and renewable energy installations implemented. Each change will have implications for biodiversity, as habitat loss from land use change is the most significant contributor to biodiversity change and decline (CBD 2024;

MEA 2005). Though land and sea use changes for climate action may decrease greenhouse gas emissions and increase carbon dioxide ($CO_2$) removals through sequestration, it is unclear how they will contribute to a "biodiversity-rich" status by 2050. It is important to determine how climate change actions impact biodiversity and its associated ecosystem services. However, there is a critical spatial component to biodiversity impacts and the value of biodiversity protection and restoration actions. Spatial land- and sea-use planning are needed to maximise climate mitigation and adaptation actions and to minimise biodiversity loss in some areas and restore biodiversity in others. Knowing where Ireland's biodiversity is located, how it is changing and the most effective ways to monitor it is urgently needed for the incorporation of biodiversity considerations into spatial land use planning.

In 2023 the All-Island Climate and Biodiversity Research Network (AICBRN) working group on carbon budgets and biodiversity expressed concern that no modelling framework currently assesses the impact of proposed carbon budget scenarios (sectoral climate actions) on biodiversity.

This working paper addresses the need to consider biodiversity impacts in the carbon budget process. It recommends ways to incorporate biodiversity into the carbon budget process by identifying and assessing the potential impacts (positive or negative) of climate action measures on biodiversity and by including assessment of actions taken primarily for biodiversity to contribute to long-term carbon storage and emissions reductions. It further suggests that a change in the carbon budget decision-making process is necessary and highlights in the impact assessment tables, actions that can already be implemented, within a broader spatial context.

# 2 Research Approach

## 2.1 Research background and brief

The work follows a call by the Climate Change Advisory Council. The brief for the project was '*to identify areas of potential synergies and conflicts between climate mitigation measures and biodiversity conservation and restoration and to provide recommendations for enhancing gains to biodiversity and ecosystem services whilst considering mitigation scenarios consistent with the broader national climate objective and ambitious carbon budgets'*.

## 2.2 Aims

- Identify and assess the alignment of existing national climate and biodiversity policy targets;

- Review approaches taken in other jurisdictions to ensure policies and measures align with climate and biodiversity objectives, concerning jurisdictions with legislated carbon budgets;
- Assess principal impacts (adverse and positive) of identified climate mitigation measures on biodiversity and ecosystem services including, but not limited to Agriculture, Land-use, Land-use change and Forestry, and Energy;
- Recommend ways to include biodiversity and ecosystem service considerations and spatial analysis into existing and future modelling frameworks for the carbon budget process; and
- Recommend ways to enhance opportunities for biodiversity and ecosystem services, climate resilience and environmental sustainability in the carbon budget process.

## 2.3 Approach

To achieve the research brief, according to the aims set, several steps were undertaken (Figure 2-1) and results are captured in the subsequent sections.

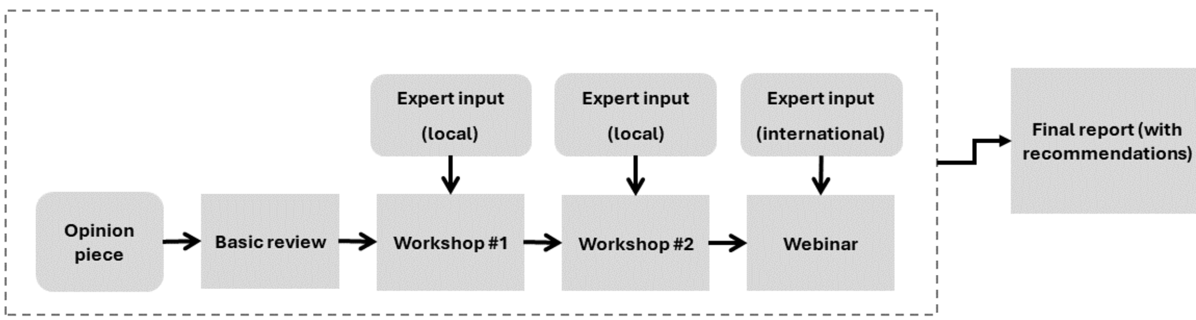


*Figure 2-1 Outline of steps to assess and recommend biodiversity considerations in the carbon budget process.*

# 3 Carbon budget and biodiversity overview

## 3.1 Carbon budget

Anthropogenic greenhouse gas emissions have increased the global surface temperature by 1.1°C, affecting the atmosphere, land, ocean, people, and nature (IPCC 2023). To address this, the United Nations Framework Convention for Climate Change (UNFCCC) and the Paris Agreement, established limits to keep the temperature increase to '*well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C*' (United Nations, 1992, 2015; Pörtner et al., 2021; IPCC, 2022). The Paris Agreement outlines the approach necessary to restrict long-term temperature increases and global emissions of greenhouse gases (United Nations 2015). Many countries are signatories to these agreements and equity is an important aspect of this approach (United Nations 2015).

Global carbon budgets are calculated using the maximum cumulative anthropogenic $CO_2$ emissions allowable for a given temperature limit and probability (Collins *et al.* 2013). Achieving the 1.5°C global carbon budget requires rapid and large reductions in $CO_2$ emissions, and substantial reductions in methane ($CH_4$) (51%) and nitrous oxide ($N_2O$) (22%). This will allow for global net zero $CO_2$ in the early 2050s, followed by net negative greenhouse gas emissions (Rogelj & Lamboll 2024). The Intergovernmental Panel on Climate Change (IPCC) define net zero $CO_2$ emissions as the 'condition in which anthropogenic $CO_2$ emissions are balanced by anthropogenic $CO_2$ removals over a specified period' (IPCC 2018).

Under the Climate Action and Low Carbon Development (Amendment) Act of Ireland, total greenhouse gas emissions need to be reduced by 51% (33.5 Mt $CO_2$ eq.[a]) by 2030, using 2018 as a reference (68.3 Mt $CO_2$ eq.[b]). In the longer term, the national carbon budget is to achieve climate neutrality by 2050 (Irish Statute Book 2021). To achieve these targets, compromises may be needed in resource use and demand management which will require high-impact systemic and behavioral changes. Ireland's carbon budget considers all greenhouse gases across sectors, including energy industries, transport and agriculture. The national carbon budget is calculated differently from the scientifically derived global carbon budget since it is derived from the global budget and often represents a per capita share of this budget.

The climate mitigation measures discussed below, and implemented to achieve climate neutrality, will have different impacts on the carbon balance through changes in greenhouse gases, carbon sequestration or carbon stocks, depending on the measure and land use. Transitioning to renewable energy sources, enhancing energy efficiency, and adopting low-carbon technologies will significantly reduce the release of greenhouse gases into the atmosphere in comparison to fossil fuel burning. Other land use measures like afforestation or improved land management, will in turn impact carbon sequestration and ultimately carbon stocks. These measures could increase the capacity of ecosystems to absorb carbon dioxide from the atmosphere. Protecting (and increasing) valuable carbon stocks in peatlands and old-growth forests are other important mitigation measures. Ambitious deployment of these mitigation measures combined with large reductions in agricultural

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[a]Mt $CO_2$ eq. = Million Tonnes of carbon dioxide equivalent

[b]This value for 2018 comes from the National Inventory Report 2021 (EPA 2021). Emissions are evaluated using the $GWP_{100}$ from IPCC AR5, total emissions using AR4 values were 67.3 Mt $CO_2$ eq. ( 2021b).This value for 2018 comes from the National Inventory Report 2021 (EPA 2021). Emissions are evaluated using the $GWP_{100}$ from IPCC AR5, total emissions using AR4 values were 67.3 Mt $CO_2$ eq ( 2021b).

greenhouse gas emissions, whilst protecting large sensitive carbon stocks, could contribute towards climate neutrality.

The 2021-2025 and 2026-2030 carbon budgets for Ireland, were used to inform models that assess different greenhouse gas emissions pathways, across sectors to achieve the 51% reduction by 2030 (CCAC 2021a). The 2031-2035 carbon budget continues the trajectory to 'climate neutrality' by the end of 2050 (CCAC 2021a). At present, these budgets do not consider other objectives of the Paris Agreement like equity, responsibility and capability (CCAC 2021b; Wheatley 2023). Hence, there is an ongoing debate on the validity of Ireland's carbon budgets and whether they satisfy the wider objectives of the Paris Agreement and if they represent the minimum level of mitigation required (e.g. Jackson & Kelleher 2023; Moriarty *et al.* 2023a; McMullin *et al.* 2024).

In 2022, total greenhouse gas emissions in Ireland were 61 Mt $CO_2$ eq. (65 Mt $CO_2$ eq. including Land Use, Land-use Change and Forestry (LULUCF)) (EPA 2024c). Energy and agriculture contributed 56.5% and 37% respectively to the total greenhouse gas emissions (EPA 2024c). Energy and transport were responsible for most $CO_2$ emissions (59% or 21 Mt $CO_2$ eq.) and agriculture for most $CH_4$ emissions (94% or 17 Mt $CO_2$ eq.). Ninety-one per cent of $N_2O$ emissions (5 Mt $CO_2$ eq.) originated from ruminant agriculture and fertiliser use (EPA 2024c). Although renewable energy is increasing, burning fossil fuels contributed to 86% of energy use in 2022 (SEAI 2023). In 2022, Land Use Land Use Change was a net source of total emissions (4 Mt $CO_2$ eq.) (EPA 2024c), but the components Forest Land and Harvested Wood Products were consistent carbon sinks. It is projected that by 2030, Forest Land will become a source of emissions as forests reach harvesting age (EPA 2024b). Grasslands and wetlands are consistent emissions sources because of the historic and ongoing drainage of organic soils (EPA 2024c)[c]. Ireland's carbon budgets are highly constrained and certain elements will add further constraint: inclusion of a sectoral ceiling for Land Use Land Use Change; exceedance of the first carbon budget; underachievement of the 5.25 Mt $CO_2$ eq. of unallocated savings in the second carbon budget; and accounting for international aviation and maritime emissions. To achieve emission reduction targets, compromises involving demand management and resource use are needed.

The IPCC combines consideration of agriculture and Land Use Land Use Change into Agriculture, Forestry and Other Land Uses (AFOLU) due to the key role that land use has for both agriculture and Land Use Land Use Change. The Agriculture, Forestry and Other Land Uses sector is unique since it mitigates climate change through greenhouse gas emission

[c]Rather than an review of the Environmental Protection Agency's National Inventory Report (EPA 2024c) some sectors and gases have been highlighted to give a limited but necessary background for this working paper.

reductions, and enhanced removals (IPCC 2019) and it shifts the focus from land use to land management. Land use emissions relate to the area they cover. In 2022, grasslands covered 59% of total land use (4.2 Mha), wetlands 17% (1.2 Mha), forest land 11% (0.8 Mha), croplands 11% (0.8 Mha), settlements 2% (0.1 Mha) and other land use 0.1% (EPA 2024c). Figure 3-1 shows the spatial distribution of some key land uses.

Several studies have evaluated different land use scenarios for greenhouse gas mitigation in Ireland (e.g. Duffy *et al.* 2020, 2022a, b; Styles & Duffy 2021). While they demonstrated that it is possible to achieve net zero greenhouse gas emissions within the biophysical limits of the land system, substantial changes in land use are required (Moriarty *et al.* 2023a). Haughey et al. (2023b), as part of the land use review, developed scenarios to determine the key components of a land transformation that would achieve climate neutrality, defined as net zero greenhouse gas emissions, and a biodiversity-rich landscape. For example, scenarios for a net zero (all gases and current accounting methods) show that AFOLU requires an annual afforestation rate of 35 kha $yr^{-1}$ (more than four times the current annual target). This will increase forest land (converted from grassland) between 2025 and 2050 by 875 kha; more than doubling the current forest area. Afforestation with broadleaf species would require additional land due to the slower growth rate compared to coniferous species. Ambitious organic soil rewetting (302 kha grassland on organic soils; 70 kha of exploited peatland), ambitious reductions in livestock system emissions and livestock numbers and ambitious land conversion from grassland to bioenergy crops or nature (420 kha) are also required (Haughey *et al.* 2023b). Recent research and subsequent inventory revisions estimate that only 90 kha, as opposed to 302 kha, of organic soil under grassland remains drained, as many drains have naturally blocked over time (Tuohy *et al.* 2023). As a result, achieving net zero under this scenario would require additional emissions reductions.

None of these studies however have included the consideration of where land use changes will be spatially located and how this might impact the spatial distribution of biodiversity and interactions with biodiversity protection and restoration measures. These land use scenarios also do not include the EU Biodiversity Strategy (EC 2020) target of 30% of land area under protection (a third of this under strict protection) or the Nature Restoration Law target of 20% of land under restoration action by 2030, and all ecosystems in need of restoration by 2050. Several biodiversity protection and restoration measures can be stacked with other land uses, enabling the achievement of synergistic social, economic, climate and biodiversity objectives. All greenhouse gas emission mitigation pathways related to land have important interactions with food, energy and biodiversity. Assessment of the compatibility of biodiversity protection and restoration targets with carbon budgets requires spatial land use scenarios and optimisation modelling.

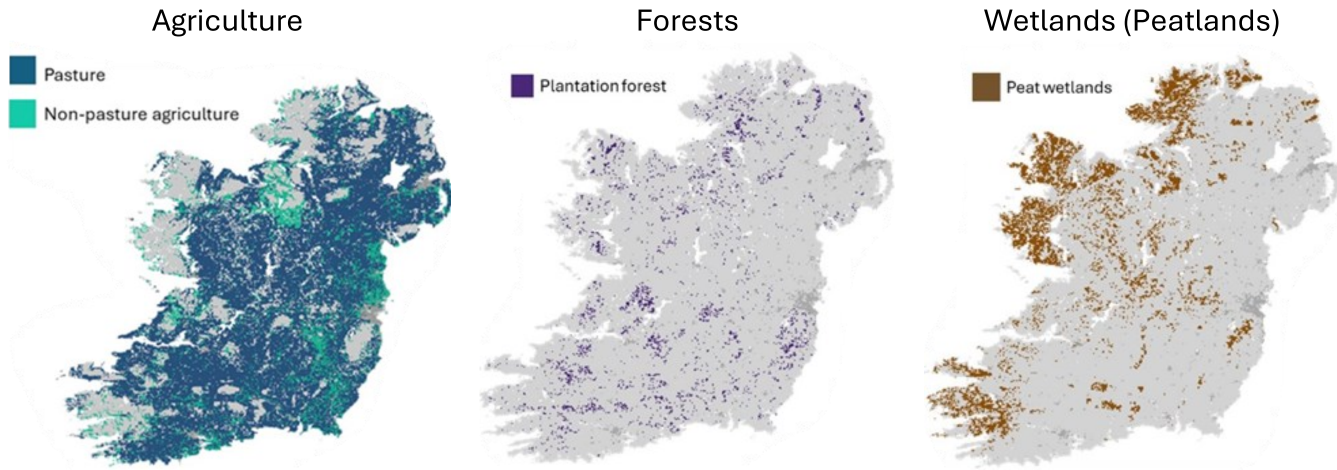


*Figure 3-1 Spatial distribution of agriculture, forests and wetlands across Ireland. Agriculture includes pasture and non-pasture agriculture (non-irrigated arable land, fruit trees and berry plantations, complex cultivation patterns, agriculture with natural vegetation), wetlands (including peatlands), and forestry (conifer plantations). Maps were from CORINE 2018 (Copernicus 2018). Land cover data was obtained between 2012 and 2018. Note: land cover is shown in the maps and used as a surrogate for land use since maps of current land use data are not readily available. CORINE data was used in place of the National Land Cover Map (EPA 2023a; Tailte Éireann 2023), a bespoke land cover map for Ireland's land cover, due to technical constraints.*

The economic cost of climate policy and mitigation measures is widely acknowledged. The United Nations Framework Convention on Climate Change already in 1992 stated that climate change policies should be cost-effective, aiming for the greatest global benefits at the lowest costs (United Nations 1992; Köberle *et al.* 2021). Much of the work aimed at estimating the macro-economic cost focuses on the mitigation measures only, and less on the impact of climate change itself, and the associated economic benefits of avoided impacts (Köberle *et al.* 2021). For example, Lanigan *et al.* (2023) provide an example of sectoral abatement cost estimation for agriculture in Ireland, but they do not consider the spatial dimensions of implementation. Busch *et al.* (2024) in their study in low- and middle-income countries, showed that abatement costs vary spatially. They showed that a combination of strategies, rather than a single strategy had the most cost-effective results. Busch *et al.* (2024) further cautioned about focusing on cost-effectiveness when selecting a reforestation method: a more cost-effective method for a specific site does not mean it is the better method for that site. When making site-specific reforestation decisions a range of factors should rather be considered: local needs, biodiversity, current land use, economics, and social constraints.

Ireland faces several challenges and uncertainties in achieving its carbon budget. A large-scale land-use transformation is required but the chosen definition of net zero greenhouse gas emissions and 'climate neutrality' will determine the level and combination of land-use change necessary (e.g. Bishop *et al.* 2024). Other uncertainties include (1) no sectoral emission ceiling for LULUCF[d], (2) ongoing revision of emissions factors related to LULUCF[e], (3) no indication of the next sectoral ceiling for agriculture, (4) lack of a land-use change pathway to close the carbon budget gap in agriculture, (5) whether Ireland's carbon budgets satisfy the 'Paris Test' (irrespective of whether the $CO_2$ warming equivalents, $GWP_{100}$ (Global Warming Potential) or split gas approach is used (Bishop *et al.* 2024). Uncertainty hampers research and modelling of these interactions, which may have positive or negative impacts on biodiversity through land use and land-use change. This is particularly important for biodiversity as environmental degradation and biodiversity loss are primarily a result of land-use change (EPA 2020b; NPWS 2019b; Pörtner *et al.* 2021b).

## 3.2 Biodiversity

Biodiversity is defined as 'the variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part' (IPBES 2019). The Irish National Citizens' Assembly on Biodiversity Loss (2022) stated "that biodiversity has an intrinsic value that should be recognised and that the essential ecosystem services it provides will be impossible to replace". The 4th National Biodiversity Action Plan for Ireland envisages that "Biodiversity in Ireland is valued, conserved, restored and sustainably used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people" (NPWS 2024). This definition recognises the intrinsic value of biodiversity and its essential underpinning of the economy and people's survival and well-being.

The National Climate Objective (DECC 2022) commits Ireland to being "biodiversity-rich" by no later than 2050. But there is no agreed definition for 'biodiversity-rich' in Ireland (see section 3.3), nevertheless, biodiversity is undoubtedly in a poor condition, according to several reports. Article 17 reporting on the condition of designated habitats under the Habitats Directive, shows that 85% of habitats are in unfavourable status (NPWS 2019a). In aquatic ecosystems, biodiversity is reliant on good water quality, but water quality is unfavourable in many river water bodies, with 44% in moderate to bad biological condition, and 45% of lakes in bad condition (EPA 2023b). Populations of important groups of species

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[d]While no Sectoral Emissions Ceiling (SEC) has been set for the LULUCF sector, the 2024 Climate Action Plan states that "The ambition for this sector shall now be a fixed reduction of 0.626 MtCO2eq. by 2030 below a baseline set at the average of the 2016-2018 emissions". The intention of this target is to pursue an approach that is more aligned to how the EU LULUCF Regulation deals with the fluctuations and limits within the LULUCF sector (EPA 2024d).

[e]Recalculations based on updated scientific information that informs emissions factors for example can result in significant changes in emissions and removals as reported in the National Inventory Report (Iversen *et al.* 2014) as is the case for recalculations in Ireland's National Inventory Reports 2023 and 2024.

(birds, bees, butterflies) have declined (NPWS 2024), and over half of Ireland's native plant species have declined in range and/or abundance (Stroh *et al.* 2023).

Ireland does not have a national habitat map, an important requirement for spatial planning for biodiversity and climate action, prediction of the extent and distribution of impacts, and targeting of mitigation and adaptation actions. The available national land cover map (EPA 2023a; Tailte Éireann 2023) can be used as a proxy for the distribution of broad habitat types and is the best national-scale distribution of broad habitats that is available. Knowing the extent and distribution of habitat types do not indicate the habitat condition e.g. the abundance and diversity of orchids in an extensive grassland, or the degree to which invasive species have established. Such assessments require detailed site visits and spatially representative ecological surveys which are repeated at regular intervals.

Biodiversity protected at Natura 2000 sites under the EU Birds and the Habitats Directives captures only a portion of relevant habitats and species populations, and not their entire distribution. Hence, areas in the wider countryside (outside of protected areas) can have a nature value similar to, or only marginally lower than, that in designated protected areas (Matin *et al.* 2020; Walsh *et al.* 2015). Biodiversity in Ireland, and the provision of related ecosystem services and benefits to people, are not confined to Protected Areas (Figure 3-2). For example, farmland outside of protected areas includes High Nature Value (HNV) farmland, defined as "areas … where agriculture is a major (usually the dominant) land use and where agriculture sustains or is associated with either a high species and habitat diversity, or the presence of species of European conservation concern, or both" (Andersen *et al.* 2004). There are extensive areas of High Nature Value farmland in Ireland; it comprises about 33% of farmland (Moran *et al.* 2021). Of the High Nature Value farmland area, around 45% has no overlap with Natura 2000 sites (Matin *et al.* 2016), highlighting the widespread distribution of farmland biodiversity in the wider countryside. Similarly, other habitats not associated with farmland e.g. sand dunes, will have examples of high biodiversity conservation value that are not necessarily within Natura 2000.

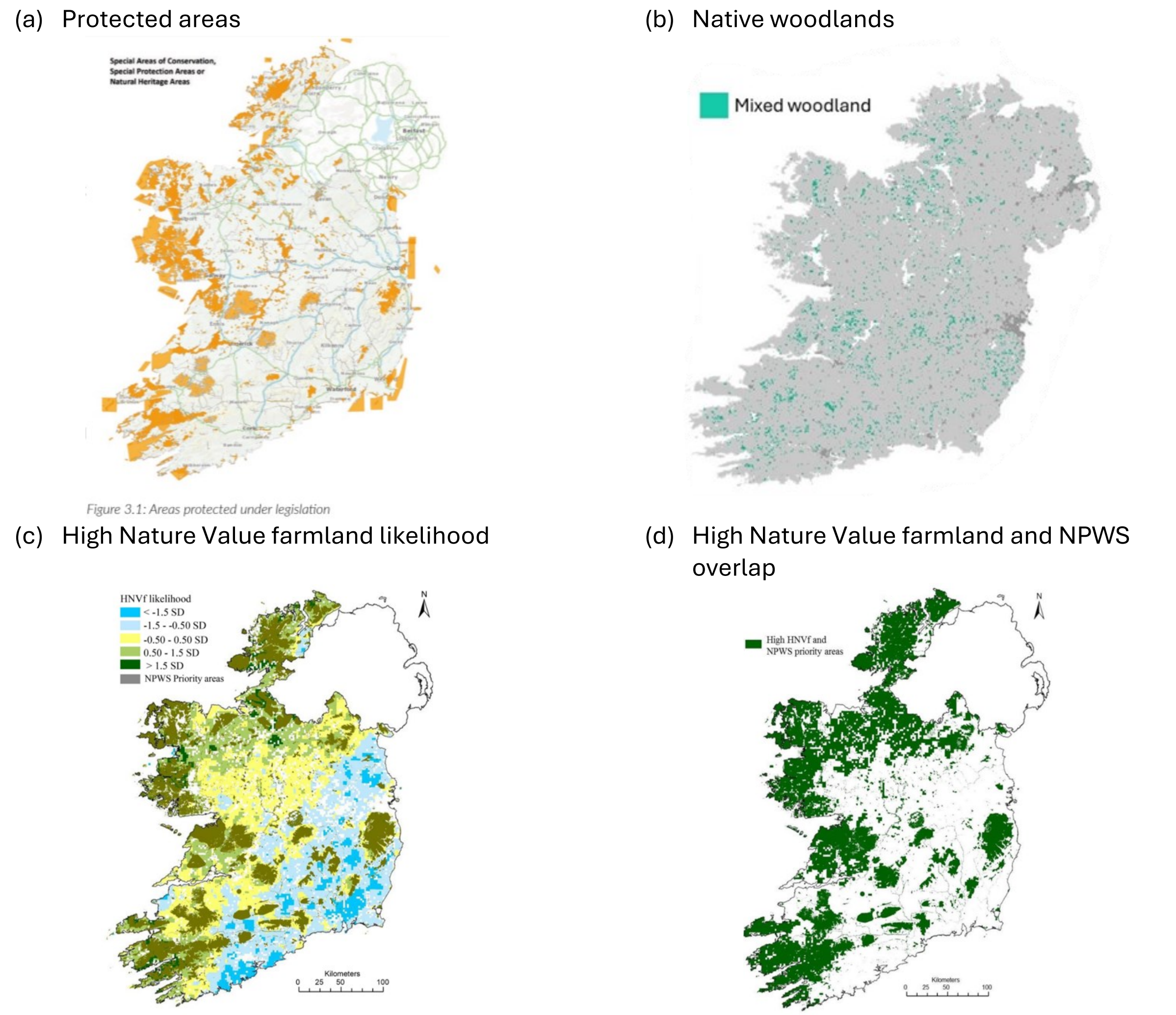


*Figure 3-2 Spatial distribution of (a) protected areas in Ireland (O'Rourke* et al. *2023) as well as areas of biodiversity importance such as (b) native woodlands (CORINE (Copernicus 2018)), (c) High Nature Value farmland likelihood, and (d) the overlap of High nature value farmland and NPWS priority areas for farmland wildlife as part of agri-environment schemes (Matin* et al. *2020)*

Ireland has several (independent) assessment and monitoring activities for biodiversity (or proxies for biodiversity). As part of the Agri-Climate Rural Environment Scheme (ACRES) farm advisers visit participating farmland and score ecosystem conditions; NPWS carries out monitoring and evaluation of Natura 2000 sites and protected species (Article 17 and 12 reporting); the National Biodiversity Data Centre collates biodiversity records from citizen scientists; the Marine Institute monitors several marine aspects; the EPA measures water quality and related species. In addition, as part of the Teagasc National Farm Survey (Teagasc 2023b), a statistically representative set of farms is sampled. Efforts are underway to include an indicator based on broad habitat types and condition assessment of selected habitats. The National Forest Inventory (DAFM 2020) assesses biodiversity in sample forests based on indicators like age (even/uneven-aged), and species composition. New initiatives are underway: DAFM has initiated a broad habitat monitoring programme (DAFM 2023) that will focus on habitats in the wider countryside, and will assess their quality (habitat condition) following the broad approach of Carlier *et al.* (2023); and the CSO is developing a national Ecosystem Accounting programme (CSO 2024) to estimate the provision of ecosystem services. A statistically representative, repeatable, and repeated national programme to monitor biodiversity specifically, including in the wider countryside, remains lacking. Ireland urgently needs a coordinated approach to understand the extent and condition of biodiversity in Protected Areas and the wider countryside, to ensure the implementation of effective targeting of measures to protect and restore it.

Knowledge from a national monitoring programme or framework will enable analysis of the biodiversity impacts of carbon budget requirements and actions. For this, both mosaic (spatially segregated) and multifunctional (spatially congruent) approaches to the spatial arrangement of biodiversity and climate actions have roles to play. Climate and biodiversity actions may be spatially segregated in a “mosaic” of mutually exclusive land uses, or climate and biodiversity actions may be co-located or stacked, possibly together with other land uses, in multi-functional sites. In all cases, additional actions (land use change) to mitigate the risk of biodiversity loss from climate action may be needed. Planning for land use change needs to consider the spatial location of biodiversity assets and their condition. Strategic spatial land use planning is essential to advise stakeholders on alternatives, and to develop schemes to incentivise change.

## 3.3 Toward a working definition of ‘biodiversity-rich’

There is an urgent need to define and clarify “biodiversity-rich” as a stated aim to be achieved by 2050 as part of the National Climate Objective (DECC 2022). This is outside the scope of the current study. This definition will need to align with other national policies that address biodiversity (e.g. National Biodiversity Action Plan). It needs to be clear to be useful for operational guidance on the policy choices and practical actions necessary for the achievement of ‘biodiversity-rich’. To assess whether the “biodiversity-rich” part of the National Climate objective is being achieved, quantitative data on the extent and condition of habitats and the status of species populations are needed. Similarly, to assess progress towards this objective, objectives, targets and indicators need to be set that can be monitored. The Nature Restoration Law requires adequate biodiversity monitoring, which will need to be initiated during the planning phase for the National Restoration Plan.

A definition of "Biodiversity-rich" is likely to include, for example: prevention of further decline of habitats and species; improvements in biodiversity through passive and active restoration; connectivity of habitats and ecosystems, and identification of effective solutions that take account of competing activities (e.g. CARE principles (Sterner & Elliott 2023)). A "biodiversity-rich" status will ensure the continued provision of essential services provided by biodiversity, like nutrient recycling in soils, pollination, pest and disease control for both food crops and natural ecosystems and support human health benefits.

# 4 Legislation and measures

## 4.1 Irish biodiversity and climate change alignment

The climate and biodiversity crises are complex, as is the associated policy landscape. Addressing them together is an opportunity to optimise the strong interactions that exist (Figure 1-1), not only between action on climate change and biodiversity loss but also in considering how solutions will affect society (Pörtner *et al.* 2021a). Denton *et al.* (2022) noted that policy silos have negative effects on policy coherence, preventing the systemic emergence of path shifts that accelerate mitigation and achieve multiple policy objectives. Since policies are progressively complex, they need to be more horizontally integrated for climate action to accelerate, for connected sustainability transitions to take place (Markard *et al.* 2020) and to achieve policy adherence (Denton *et al.* 2022; Dubash *et al.* 2022).

Biodiversity and carbon budgets are addressed through various independent policies, action plans, programmes, and frameworks at global, regional (EU), and national levels. Since policies typically relate to a specific challenge or sector they are regulated by different governmental departments or state agencies. For example, in Ireland, climate action and biodiversity policies are divided between DAFM, DECC, OPW, and Bord na Móna (Haughey et al. 2023a). RPS (2024b) provides an extensive overview of some of the policies and measures relevant to Ireland (Figure 4-1).

In recent years there has been an increased awareness and acknowledgement that climate change, biodiversity change and loss and water quality deterioration are challenges that need to be addressed together, which is reflected in Irish policies. Simply searching for 'biodiversity' in the Climate Action Plan 2024 (CAP24) (DECC 2023) shows that this term occurs 59 times; searching for 'climate change' in the National Biodiversity Action Plan (NBAP) (NPWS 2024) shows a total occurrence of 28 times. The NBAP recognises the link between the two crises, highlighting the importance of healthy ecosystems for protection against climate change. Similarly, the impact assessments done for the most recent CAP 24 (Natura Impact Assessment (RPS 2024a); Strategic Environmental Assessment (RPS

2024b)) acknowledge that ill-considered climate actions could have detrimental impacts on biodiversity.

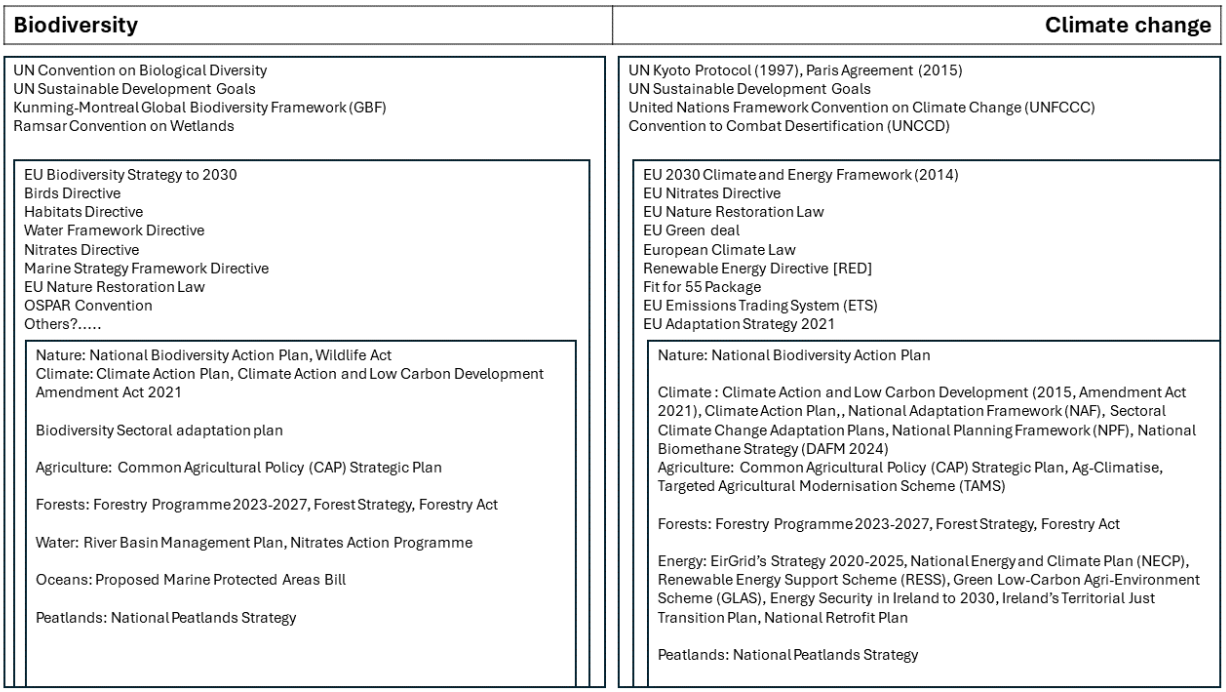


*Figure 4-1 Overview of policies, policies, action plans, programmes (schemes), and frameworks related/applicable to biodiversity and climate change, at a global, regional (European Union) and national scale.*

Despite this, the current integration of climate and biodiversity policy remains shallow. Much more integration is required across all departments and sectors, including e.g. health. Much more needs to be done and at a faster pace to tackle climate change and biodiversity loss and to create an integrated strategy for land use that can deliver on climate and biodiversity actions, drawing out the synergies and trade-offs and managing them to get the most synergistic benefits, whilst minimising negative impacts as much as possible (Moriarty *et al.* 2023b). Integration is likely less restricted by challenges posed to integrated biophysical modelling (links are being explored more explicitly, e.g. Weiskopf *et al.* (2024)). But more likely due to the lack of spatial data and an integrated strategy (across climate change mitigation and biodiversity) to transform land utilisation.

## 4.2 International jurisdiction overlaps

Internationally, biodiversity and climate change policies lack horizontal integration. Below we discuss two jurisdictions that share climate change and biodiversity challenges with Ireland: Finland and New Zealand.

### 4.2.1 Case study: Finland

Finland aims to be climate neutral by 2035, earlier than their EU target. To achieve this, Finland relies on an increased carbon sink from the land use sector. Between 1990 and 2020, LULUCF was an important carbon sink (3-55% of total emissions) (Statistics Finland 2022 in Forsius *et al.* 2023) but in 2021 it became an emissions source due to an increase in harvesting. Other land use activities, like improved farming, forest management, peatlands management and protection, can also help with achieving their carbon budget. The 'Climate Plan for the Land use sector', 'Carbon neutral Finland 2035' and the 'National Forestry Strategy 2035' provide more details. The land uses important from a carbon storage and sequestration perspective, are also important habitats for threatened and endangered species. About 33% of threatened species live only in forests and 9% of forest species are endangered (Table 4-1).

*Table 4-1 Overview of key aspects related to climate change, biodiversity and land use in Finland. Reference is made to legislation, emission reduction targets and land use.*

| ***Aspect*** | **Details** | ***Aspect*** | **Details** |
|---|---|---|---|
| *National climate legislation* | National Climate Act 2022<br>National Climate Change Adaptation Plan<br>Medium-term Climate Plan (KAISU)<br>Climate Plan for the Land Use Sector (MISU)<br>National Energy and Climate Strategy<br>Carbon neutral Finland 2035 | Land use (% of total area) | Forests: 75% (23% of commercial forest land protected; or limited forestry purpose)<br>Agriculture: 8%<br>Other land uses (wetlands, etc): 17%<br>Peatland: 30% (~50% drained) |
| *National biodiversity legislation* | Strategy for the Conservation and Sustainable Use of Biodiversity<br>Finland's Nature Conservation Act | Land area ($km^2$) | 338,145 |
| *Climate ambitions* | National:<br>2035: climate neutrality<br>EU ambitions:<br>2035: 55% national greenhouse gas reductions from 1990<br>2050: climate neutrality<br>2030: 62% reductions in the Emissions trading sector (ETs), from 2005<br>2030: 50% reductions in the Non-ETS (effort sharing) sector, from 2005<br>Land use sector:<br>2021–2025: net emission=0<br>2026-2030: increase in emissions sink (17.8 Mt) | Other important measures | National Forest Act<br>National Forest Strategy 2035<br>Helmi, Metso programmes |

The Finnish Climate Change Act is progressive in that it requires an assessment of the impact of the mitigation measures proposed. However, it states that it may not be possible '*to identify all environmental impacts. Instead, the aim of environmental impact assessment is to identify the key impacts and impact chains of measures*'.

- *'Under the Act on the Assessment of the Effects of Certain Plans and Programmes on the Environment (SEA Act, 200/2005), an authority must investigate and assess the environmental impacts of the plans and programmes it has prepared to a sufficient extent during the preparation process (section 3), if their implementation may result* *in significant impacts on human beings, nature and its diversity, the built environment, landscape or natural resources in Finland or outside its region (section 2).'*

- *In accordance with the SEA act, these environmental impacts include impacts affecting: the population and human health, living conditions and comfort; soil, waters, air, climate, vegetation, organisms and biodiversity; urban structure, the built environment, landscape, townscape and cultural heritage; natural resources use; and any interactions between the factors listed above'*.

Also, the Strategy for the 'Conservation and Sustainable Use of Biodiversity' (Ministry of the Environment 2024a) and the 'Conservation Act' (Ministry of the Environment 2024b) both aim to protect biodiversity; the former through sustainable use and the latter through protection and restoration. The 'National Forestry Strategy 2035' aims to improve biodiversity, in addition to its carbon aims, also focusing on sustainable forest use.

The climate-biodiversity-land use policy nexus necessitates a balance between the targets and measures of greenhouse gas emissions reductions and carbon stock protection, (sustainable) utilisation of land use resources, conservation of habitat and species, and other sustainable development goals. Forsius *et al.* (2023) note that 'spatially explicit dynamic modelling and optimization methods which can support sustainable resource management and explore potential win-win or trade-off situations regarding both climate change mitigation and conservation are therefore needed'.

To discuss the biodiversity, carbon budget and policy alignment and challenges, the 'Irish Carbon Budgets and Biodiversity' online webinar took place on 18 June 2024. Three Finnish researchers spoke about the importance of land use, biodiversity-carbon trade-offs and using spatial data and tools for optimising land use priorities.

Prof Laine-Petäjäkangas from the University of Eastern Finland talked about 'Peatland restoration in Finland, impacts on biodiversity and climate'. Two critical points that she raised were:

- Peatlands and forests are important carbon stocks and are biodiversity-rich. They should be protected and where possible restored. Drainage of peatland causes a lot of emissions.
- When considering restoration pathways, a 'win-win' situation for all ecosystem services will not (always) be possible. Various pathways and sites need to be used to achieve a range of ecosystem services as shown in Figure 4-2 (Laine *et al.* 2024). These should be spatially distributed across the landscape and include small unique, biodiversity-rich land uses.

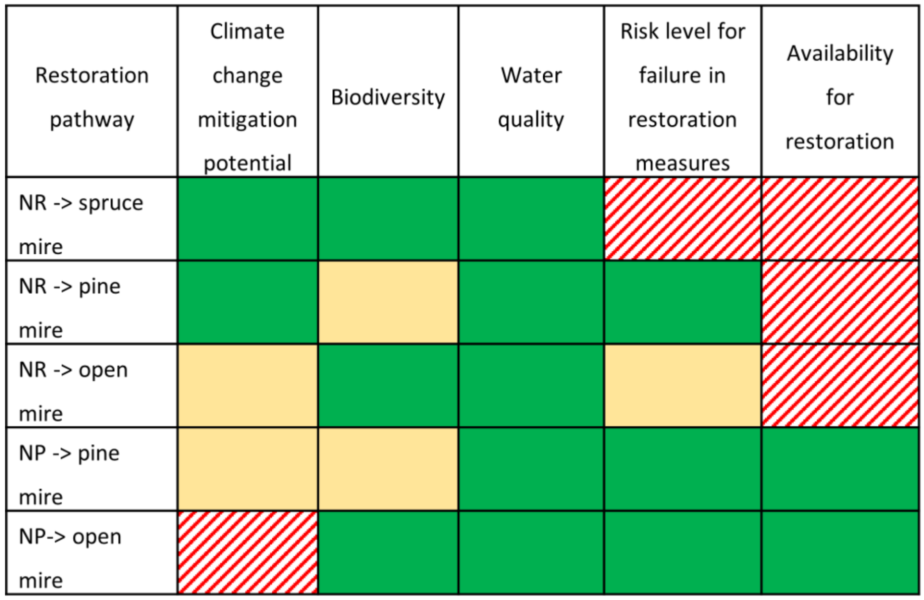


*Figure 4-2 Illustration of an impact assessment of different restoration pathways on a range of ecosystem services as presented by Laine* et al. *(2024). Red hatched cells represent negative impact, green (dark) positive and yellow (light) neutral. NR and NP refer to nutrient-rich and nutrient-poor forestry-drained peatlands, respectively.*

Prof Santtu Kareksela from Parks & Wildlife Finland talked about 'Restoration prioritization at various scales' including the following points:

- Consider trade-offs as part of prioritization and decision-making. Win-win-wins should be at a national scale. At a local or regional scale, there will be wins for some ecosystem services and losses for others. If one emphasises one ecosystem service another will receive less emphasis. 'Think national, act local'.
- Consider scale. Some habitats and biodiversity only occur in one place and should be protected. Climate mitigation can occur in many places. The protection of many small biodiversity-rich areas may be efficient (cost and species). Consider species rarity in a broader context (e.g. EU region) than your own country.
- Spatial tools like Zonation are very useful in prioritisation of areas of restoration.

Prof Martin Forsius from the Finnish Environmental Institute expanded in his talk 'Carbon and biodiversity interactions in Finnish forested ecosystems' on how carbon scenario modelling and biodiversity prioritisation are combined and optimised spatially, including these points:

- Statistical analysis using available spatial datasets can be used to evaluate the drivers of increases in nutrients in water sources (Finér *et al.* 2021; Räike *et al.* 2024). Finland showed increases in nitrogen, phosphorous and total organic carbon in all water sources.
- It is possible to model carbon balance mitigation scenarios spatially and consider biodiversity protection priorities, such a framework is used in Finland (Figure 4-3). A

spatial representation allows one to look at the regional impacts of mitigation scenarios on both emissions and carbon stocks (Forsius *et al.* 2023; Holmberg *et al.* 2023). It allows one to optimise land use and associated services across the landscape (country) (Figure 4-4)(Forsius *et al.* 2021).

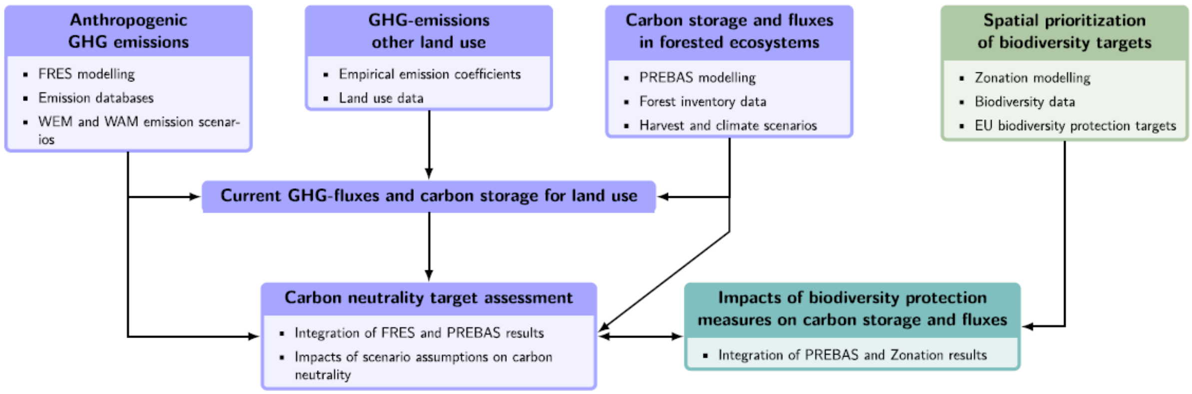


*Figure 4-3 Framework and flow of data for modelling and evaluation used by Forsius* et al. *(2023).*

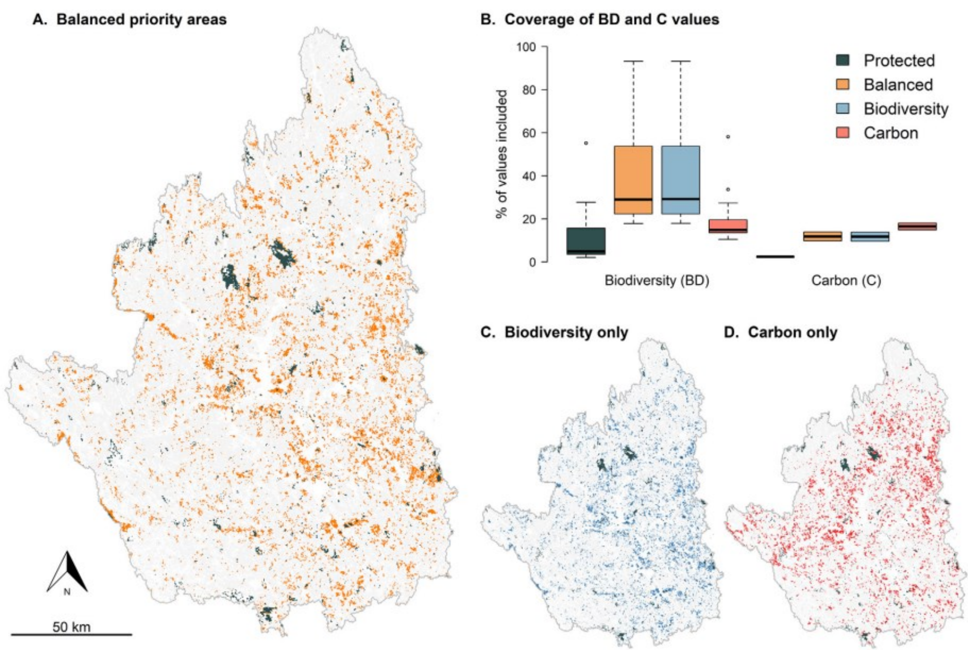


*Figure 4-4 From Forsius et al. (2021). Maps show landscape prioritization for biodiversity and carbon in the Kokemäenjoki river basin. All maps show the currently protected areas (in dark grey) and the best 10% of forests on mineral soils, where harvesting should be avoided (in colour). Panel A) gives the integrated balanced priority areas (in orange) that maximize both biodiversity values and carbon pools and fluxes. Panels C) and D) show priority areas for biodiversity only (in blue) and carbon only (in red), respectively. Boxplots in panel B) show how much these priority areas capture of the total values within mineral soil forests, shown separately for biodiversity (dead wood potential, old forests, threatened species and focal birds) and carbon (pool and fluxes) features (x-axis), and for currently protected areas and the three different priority solutions (A, C, D) (boxplots).*

Learnings from Finland for Ireland:

- Regional implementation of biodiversity and carbon priorities so that targets are achieved nationally (win-win for IE);
- Acknowledge that one land parcel (land use) may not provide all environmental services or benefits: optimise the use of land use resources for services and accept trade-offs;
- Protect large carbon stores like peatlands which are often also rich in biodiversity; protection and restoration will increase the resilience of these land uses to future climate change;
- Protect unique habitats for biodiversity (e.g. high nature value farmland) that often cover small areas: certain species only occur in one place; and
- Invest in spatial data collection, spatial modelling and spatial prioritisation, for regional assessment.

### 4.2.2 Case study: Aotearoa New Zealand

New Zealand remains a net emitter of GHGs, but emissions showed a further gross reduction (4%) from 2021 to 2022. Agricultural emissions remain high (53% of total emissions), but they decreased by 1.4% from 2021 to 2022 (Table 4-2), mainly due to lower livestock numbers and a decrease in the use of synthetic fertilisers. Most of the agriculture emissions were from $CH_4$ (43.1% of total emissions). Energy emissions decreased by 8.1% from 2021 to 2022. Energy emissions were dominated by emissions from transport and contributed to 17.5% of the total greenhouse gas emissions for New Zealand. Contributions to emissions from electricity generation are small due to the large renewable energy component (87%). Greenhouse gas emissions in New Zealand are offset by LULUCF removals (25%), although this contribution decreased by 6% between 2021 and 2022. This was due to an earlier harvest date due to increased demand for timber and hence a younger stand age of planted forest estates. LULUCF emission removals are the result of the 86 kha of forests planted in 2022 and the afforestation incentives under the Emissions Trading Scheme (ETS).

The report 'Biodiversity in Aotearoa an overview of state, trends and pressures' (Department of Conservation, 2020) highlights the important pressures on biodiversity, like changes in land and sea use; direct exploitation; climate change; pollution and introduced invasive species. There have been substantial changes in indigenous vegetation or land, to exotic grass and forest species and 95% of all native vegetation that has been lost disappeared from land that was not legally protected (Department of Conservation, 2020). About 33% of New Zealand's total land area has small areas of native vegetation cover (less than 20% land cover). It is therefore important to consider the impact of any land use change on biodiversity.

New Zealand is subject to several national legislative measures like the Climate Change Response (Zero Carbon) Amendment Act (2019) aimed at reducing greenhouse gas emissions and reaching net zero emissions by 2050 (CH4 emissions excluded) as set out through 'Aotearoa New Zealand's First Emissions Reduction Plan 2022 (Table 4-2), and the New Zealand Emissions Trading Scheme (NZ ETS) which allows for emission reductions through afforestation. New Zealand biodiversity is protected through separate measures like Te Mana o te Taiao – Aotearoa New Zealand Biodiversity Strategy 2020 (ANZBS) and the National Policy Statement on Indigenous Biodiversity (NPSIB).

*Table 4-2 Overview of key aspects related to climate change, biodiversity and land use in Aotearoa New Zealand. Reference is made to legislation, emission reduction targets and land use.*

| ***Aspect*** | **Details** | ***Aspect*** | **Details** |
|---|---|---|---|
| *National climate legislation, measures* | Climate Change Response Act 2002<br>Climate Change Response (Zero Carbon) Amendment Act in 2019<br>Climate Change Response (Emissions Trading Reform) Amendment Act (proposed 2024)<br>New Zealand Emissions Trading Scheme (NZ ETS)<br>Aotearoa New Zealand's First Emissions Reduction Plan 2022<br>Climate Change Strategy 2024<br>National adaptation plan<br>2024: First inventory report under the Paris Agreement, UNFCCC (using new GWP values) (previous UNFCCC, Kyoto) | *Land use (% of total area)* | Agriculture: 40% (exotic grassland)<br>Cropping, horticulture: 2%<br>Exotic forests: 8%<br>Native forests: 30%<br>Indigenous land cover (native vegetation): 20%<br>Urban land cover (built-up areas): <1%<br><br>Land area ($km^2$): 268,021 $km^2$ |
| *National biodiversity legislation, measures* | Te Mana o te Taiao – Aotearoa New Zealand Biodiversity Strategy 2020 (ANZBS)<br>National Policy Statement on Indigenous Biodiversity (NPSIB)<br>Convention on Biological Diversity<br>Farm management plans<br>National Policy Statements and Standards (Indigenous biodiversity, Freshwater, Productive lands, Plantation forests, Drinking water) | *2022 Greenhouse gas emissions (% of total)* | Agriculture: 53%<br>Energy: 37% (17.5% transport))<br>Industry: 5.7%<br>Waste: 4.5%<br>LULUCF: -25% removals*<br><br>CH4: 49%; N2O: 9%, CO2: 40%<br>Gross Emissions: 78.4 Mt $CO_2$ eq.;<br>LULUCF removals:19.2 Mt $CO_2$ eq. |
| *Climate ambitions (targets)* | 2030: 50% net emissions reductions below 2005 values<br>2030: 10% reduction in biogenic $CH_4$ emissions below 2017 values<br><br>2050: Net zero (for all greenhouse gas emissions other than biogenic $CH_4$)**<br>2050: 24-47% reduction below 2017 biogenic $CH_4$ emissions NDC1) | *Other important measures, reports* | Biodiversity credit scheme (explored)<br><br>Ināia tonu nei: a low emissions future for Aotearoaa 2021<br>A framework for the National climate change risk assessment for Aotearoa New Zealand<br>Forestry: National Environmental Standards for Commercial Forestry (NES-CF)<br>Natural and Built Environments Bill (NBA) – proposed<br>Strategic Planning Bill (SPA) – proposed<br>Climate Adaptation Act (CAA) – proposed<br>Financing schemes:<br>New Zealand Green Investment Finance<br>Decarbonising Industry fund<br>Carbon Neutral Government Programme<br>State Sector Decarbonisation Fund<br>Clean Vehicle Discount |

Substantial emission reductions are required to reach net zero in 2050, which will require substantial and sustained emission reduction measures with the potential to impact ecosystem services like biodiversity and water. Some of the proposed plans integrate or make provisions for biodiversity considerations in climate change mitigation. This is often related to nature-based solutions, but it shows an acknowledgement that biodiversity should be considered formally when mitigation measures are considered and implemented.

For example, the Aotearoa New Zealand's First Emissions Reduction Plan 2022 (Ministry for the Environment 2022b) provide some key actions related to nature-based solutions:

- *'encouraging greater levels of native afforestation to build a long-term carbon sink (where carbon dioxide is removed from the atmosphere) that supports biodiversity*
- *reducing the costs of restoring our native forests and delivering pest control that will help our native ecosystems thrive and remove more carbon....'*.

Also, specifically related to Forestry (Ministry for the Environment 2022a): *'Forestry provides long-term carbon sinks, supports biodiversity, and contributes to our bioeconomy and equitable transition.'*

Similarly, in the National adaptation plan (Ministry for the Environment 2022c), the government states that it '*will embed climate resilience across all its strategies and policies'*; and that when '*ecosystems are healthy and diverse, they can adjust more effectively to climate threats'*...

Also, *'to support healthy, connected ecosystems, where biodiversity thrives, the Government will'*:

- *'implement key biodiversity policies and strategies to protect, restore and build resilience of indigenous biodiversity to climate change', and other measures....*
- *Recognising that safeguarding biodiversity and ecosystems is fundamental to our climate response; precious native ecosystems can buffer us from the impacts of climate change, store carbon, support biodiversity and improve community wellbeing'*.
- *'to address the climate and biodiversity crises together, the Government will:*
    - *prioritise nature-based solutions to adapt to climate change and deliver other socioeconomic and environmental benefits, embed nature-based solutions in transport policies and identify options to increase their integration into urban form*
    - *establish an integrated work programme to deliver climate, biodiversity and wider environmental outcomes'*.

The importance of considering the impact of the mitigation measures on biodiversity to ensure functioning, sustainable and resilient landscapes is acknowledged in the report Ināia tonu nei: a low emissions future for Aotearoa 2021 by the He Pou a Rangi the Climate Change Commission 2021 (Climate Change Commission 2021a) reviews the future carbon budgets for NZ and presents '*ambitious, achievable and equitable paths that Aotearoa can take to meet its emission reduction targets'*. They provide clear recommendations for different sectors to achieve the emission reduction targets. They also state that '*Policies must target a range of different problems and can reduce emissions in a way that supports other goals. The transition to low emissions presents opportunities to contribute to health, freshwater quality, biodiversity, reducing existing inequities, and addressing historic grievances*' and that '*Actions to reduce emissions may also have other benefits, such as for health or biodiversity. These wider benefits can justify certain policies to reduce emissions, even if when judged by their ability to reduce emissions alone, they are not cost-effective'*.

With the strong emphasis on LULUCF to offset greenhouse gas emissions from other sectors, it is important to carefully consider and implement the mitigation activities proposed (Climate Change Commission 2021b). But also, to have access to spatial data showing the distribution of different land uses.

During the online 'Carbon Budgets and Biodiversity' webinar, two researchers from New Zealand shared some insights into some of the biodiversity-carbon-related challenges in New Zealand that they are working on.

Prof Cate Macinnis-Ng from the University of Auckland spoke about 'Climate change, biodiversity and forests in New Zealand: An ecophysiological perspective'. Two important points:

- Fast-growing exotic species are often favoured for their carbon benefits (sequestration, stock, harvested wood products) but they often have negative impacts on biodiversity (where they are planted as monocultures, or where they are rewilding or become invasive) and on available water resources.
- Much is unknown about the response of many species to climate change under future climates. Increasing our understanding to prepare better for the future is essential. Trees, for example, are expected to be faster growing, but shorter-lived (exotic and indigenous); so there may be faster carbon sequestration, but smaller carbon stocks.

Prof Bradley Case presented on behalf of himself and Prof Hannah Buckley (University of Auckland) on 'Carbon and biodiversity co-benefits? The Aotearoa New Zealand perspective'. Important points include:

- Policies sometimes have unintended (negative) consequences. The Emissions trading scheme (ETS) is currently driving large-scale afforestation. The increased value of the carbon credits has placed the focus on afforestation with exotic fast-growing species without careful consideration of the afforested sites. Hence having detrimental effects (erosion, biodiversity loss).
- Native woody vegetation (in addition to forests) is a potentially important nature-based solution for multiple ecosystem services (Suryaningrum *et al.* 2023). The extent thereof in production systems is not well known (Pannell *et al.* 2021). Spatial planning to optimize the benefits of revegetation should be done from a national to landscape to farm-scale level (Case *et al.* 2023).
- Establishing long-term monitoring sites in different landscapes provides important information on the impact of e.g. restoration measures on C, biodiversity, and other services.

Learnings from Aotearoa New Zealand for Ireland:

- Take care of how incentivised policies and mitigation measures are implemented to avoid unintended consequences.
- Optimise the benefits of native woody vegetation.
- Implement spatial planning at different levels and evaluate multifunctional tradeoffs.
- Establish long-term monitoring networks.

# 5 Impact of mitigation measures on carbon and biodiversity

## 5.1 Energy sector overview

Ireland remains very reliant on fossil fuels. In 2022, 56.3% of the emissions were from burning fossil fuels and other non-renewable fuels for energy (SEAI 2024). Continued reliance on fossil fuels will drive biodiversity loss indirectly through climate change and directly through habitat loss and pollution (Harfoot *et al.* 2018). It is therefore necessary to move towards renewable energy technologies and biofuel crops to reduce emissions and achieve our budget targets. However, climate actions in this sector must consider biodiversity, as these measures can have both positive and negative impacts, and therefore require an integrated land management strategy.

Renewable energy infrastructure and crops for biofuel have potentially positive impacts on biodiversity through climate mitigation, reduction of air pollution, and provision of alternatives to chemical fertilisers (e.g. digestate from biomethane (DAFM 2024)). However, large-scale adoption of renewable energy and biofuel monocultures may have biodiversity conflicts. These include habitat loss, degradation, and fragmentation, vegetation disturbance, suppression of ecosystem functions, disturbance of species behaviour, and species mortality *via* collision (Gasparatos *et al.* 2017; Hastik *et al.* 2015; Hellmann & Verburg 2010; Katzner *et al.* 2019; Laranjeiro *et al.* 2018; Rehbein *et al.* 2020).

Negative impacts on biodiversity can be mitigated through a lower demand, more efficient energy system, where less energy generation capacity is required. That can be achieved by lowering the demand for final energy services (e.g., in transport by switching to public and active travel modes, limiting air travel; in buildings with retrofitting), and using more efficient energy carriers (electricity) (Gaur *et al.* 2022). Negative impacts can also be mitigated by prioritising forms of renewable energy that require less land. The energy efficiency of land used for biofuels tends to be lower than for wind and solar energy (Searchinger *et al.* 2017). Potential conflicts between biodiversity and onshore wind energy seem to be lower than for biofuel.

Converting to renewable energy will have some negative impacts on biodiversity, but there are opportunities to add mitigation measures, reduce impacts and even improve the biodiversity status of renewable energy sites. The cost of not reducing emissions is much higher because climate change exacerbates negative impacts on biodiversity and ecosystems (Pörtner *et al.* 2021a). Appropriate siting of renewable energy installations is critical (Gorman *et al.* 2023), which requires knowledge of the spatial distribution of biodiversity and its incorporation into sensitivity mapping of renewable energy infrastructure impacts.

### 5.1.1 Onshore wind

The Climate Action Plan 2024 (CAP24) (DECC 2023) has set a target of deploying 9 GW of onshore wind energy capacity by 2030 for Ireland to achieve its decarbonisation goals. A land area of 2,428 ha is needed to produce this much energy, based on the method of calculation by Caslin (2024). This accounts for 0.04% of Ireland's total land area and 0.05% of agricultural land.

The vertical scale of onshore wind energy installations allows for other uses of the same land (grazing livestock, forestry or enhancing biodiversity), and provides environmental benefits compared to fossil fuel power plants (Sander *et al.* 2024). However, when inappropriately sited, designed, or managed, onshore wind farms have detrimental impacts on sensitive habitats and species. Turbines can cause bird and bat collisions, leading to injury or mortality (Roddis 2018; Wang *et al.* 2015). Onshore wind infrastructure can also increase habitat loss and fragmentation, and there have been instances of erosion and landslides in

Ireland linked to wind farm construction and excavation work (e.g. Derrybrien, Meenbog, Derrysallagh). Compared to fossil fuel power stations which cause bird death throughout the fuel cycle (mining, onsite collision and electrocution, downstream poisoning, fossil fuel burning), wind energy developments cause fewer bird deaths (Sovacool 2012).

Projects like Nature+Energy (https://www.marei.ie/project/natureenergy/) aim to enhance biodiversity on onshore wind farms in Ireland so they can provide more ecosystem services including pollination, water filtration, and habitat provision. This reduces carbon emissions through the provision of renewable energy but also enhances and protects biodiversity and ecosystem services through environmental monitoring, biodiversity action plans and natural capital accounting.

#### 5.1.2 Offshore wind

Ireland has a maritime area of 4.9 million ha, around seven times the size of our landmass. This offers significant potential for offshore renewable energy installations from wind, wave, and tidal sources. A target of at least 5 GW of offshore wind energy by 2030 has been set out in the CAP24 (DECC 2023).

Installations in marine systems can negatively impact marine biodiversity and ecosystems. Impacts may include destruction of seabeds, disturbance of fish populations and marine mammals from noise and changes in hydrodynamic conditions and water quality, collisions with seabirds, and degradation of habitats (Vaissière *et al.* 2014). Evidence suggests that the negative impacts are greatest during the construction phase, but long-term disturbances of local marine biodiversity during the operational phase have also been noted – some seabird species may largely avoid wind farm areas. To reduce the risk to marine biodiversity, various mitigation measures can be implemented: considering the timing of construction and repairs, location of the renewable installation and its design, and use of measures to temporarily disperse affected species (Wilhelmsson *et al.* 2010).

The subsurface marine environment may benefit from the installation of offshore renewable developments. To prevent the risk of collisions, ensure the safety of sailors, and preserve the integrity of infrastructure, most European countries have restricted or banned navigation within wind farms and in a buffer safety zone (European MSP 2024). Trawling is a major threat to the marine environment and restricting this within energy installations allows many species of fish and invertebrates to thrive. Turbine foundations can also function as artificial reefs and locally enhance several species (Wilhelmsson *et al.* 2010).

All steps should be taken to avoid negative impacts of offshore energy developments during the construction and long-term operational phases. Carbon-rich environments like seagrasses should be avoided, along with important migration, feeding, and breeding routes.

Marine Protected Areas (MPAs) that are to be designated (30% MPA coverage of our maritime area by 2030 (DECC 2023)) should also be avoided. Excluding designated MPAs, there is still potentially 3.4 Mha of maritime area available for offshore renewable energy developments.

Knowledge of the spatial distribution of biodiversity and sensitivity mapping is required to minimise harm to biodiversity; ongoing monitoring will be vital to identify whether mitigation measures have been successful in avoiding or reducing impacts on marine biodiversity. Monitoring can inform future environmental impact assessments for offshore renewable energy developments.

#### 5.1.3 Solar Photovoltaic

For solar photovoltaic (PV), the 2030 target is 8 GW (DECC 2023). This is equivalent to around 16 kha (0.3% of agricultural land) if this target were to be reached exclusively via larger-scale solar PV arrays, not including microgeneration and smaller-scale generation installations (Caslin 2024). While it may not be practical for larger animals (cows) to graze alongside solar PV installations, it may be possible for smaller livestock (sheep) to do so. There is also the potential to use the land under solar PV to grow food crops and increase land productivity and food security (Valle *et al.* 2017) using nature-friendly farming methods that will benefit biodiversity.

More research is required to determine the biodiversity consequences of utility-scale solar installations in Ireland and appropriate co-land-uses. The FOREST research project is investigating the compatibility of nature-based solutions together with solar installations (https://www.tcd.ie/e3/forest/project/).

#### 5.1.4 Biofuel

If Ireland is to invest in biofuel, it will require the most land out of all the renewable energy targets. To meet the biomethane target of 5.7 TWh by 2030, a total land area of 120 kha (less than 3% of available agricultural land) is needed to cultivate the necessary feedstocks for anaerobic digestion plants. Anaerobic Digestion plants that produce biomethane will likely use a mixture of both grass and slurry. Along with 120 kha necessary for silage cultivation for these plants, winter slurry from around 1.3 million cattle is needed, which is around 20% of all winter cattle slurry production in Ireland (Caslin 2024).

Other biofuel crops like miscanthus and short rotation coppice willow can be combusted in boilers and Combined Heat and Power (CHP) plants to produce heat/power; starch and oil crops can be used in refineries to produce transport biofuels.

Cultivating this amount of agricultural land either reduces the amount of land available for food production or takes land out of other land uses (e.g. primarily for nature) and may need to take land by reducing the number of livestock grazing or increasing land productivity (SEAI

2022). Allocating large areas of land for biofuel may have negative impacts on biodiversity if implemented in natural landscapes and ecologically important areas, as these would be replaced with monocultures of feedstocks (Hellmann & Verburg 2010), reducing species diversity and ecosystem services.

Due to the potential negative impacts of biofuel production on biodiversity, when using agricultural land for feedstocks for anaerobic digestion plants, High Nature Value farmland, semi-natural grasslands, commonage, Natura sites and former peatlands should be avoided if intensification of production is required. Strategies for switching land use from livestock production to low-intensity biofuel production should be explored, including the potential use of residues from conservation management (e.g. mowings) for biofuel production. However, the biodiversity consequences of a change in grassland management from livestock production to mown grass need to be carefully considered as these are not equivalent biodiversity management methods; since this grass harvesting method will also be very emission intensive.

As well as reducing Ireland's energy emissions, digestate, a by-product of anaerobic digestion rich in nitrogen (N), phosphorous (P) and potassium (K), can serve as an alternative to chemical fertiliser (DAFM 2024). The reduced use of chemical fertiliser is positive for biodiversity, soil, and water quality.

## 5.2 Agriculture, forestry, and other land use overview

Ireland faces a particular challenge to reach net zero greenhouse gas emissions because its land sector is a net source of approximately 4 Mt $CO_2$ eq. $yr^{-1}$ (EPA 2024d), rather than a net sink as in most European countries. Grassland and wetlands emit 2.5 and 3.8 Mt $CO_2$ eq. $yr^{-1}$ net, whilst forestry and wood products have a net sink of 2.4 Mt $CO_2$ eq. $yr^{-1}$ – although this sink will flip into a source later this decade owing to low rates of planting and a projected increase in harvest  (EPA 2024d). Key Climate Action Plan targets for the LULUCF sector revolve around raising the water table under drained organic soils, restoring exploited wetlands, managing existing forestry and accelerating the creation of new forestry (DECC 2023). In their recent study, Styles et al. (2024) concluded from their scenario-based modelling study that substantial changes need to be made to the agricultural industry to reach the 2050 carbon budget target including the measures mentioned above. They highlight the fact that several emissions/removals-land use scenarios will achieve this target and that stakeholders will need to decide which are the most desirable in terms of socio-economic and other factors.

### 5.2.1 Agriculture

The agricultural sector, as considered by UNFCCC, includes agricultural activities and their associated emissions. This includes emissions from livestock management on existing agricultural land (grassland for grazing, cropland for feed production) as well as emissions from fertiliser use and tilling practices on cropland. Land cover data shows that 4.76 Mha of Irish land is used for agriculture (67.6% of the national land cover) (EPA 2020a). Pasture, silage, and hay accounts for 80.6% (3.7 Mha) of the area farmed in 2019, 11.5% (451,537 ha) was rough grazing, and 7.9% crop production (265,592 ha devoted to cereals, 92,208 ha to other crops, fruit, and horticulture). An estimated 82.1% of the Agricultural Area Utilised in Ireland is under grassland.

Modelling of land use by farm system types based on data from the National Farm Survey (Teagasc 2023b) and methodology described in Henn *et al*. (2024) indicates that beef farming occupies around 2.2 Mha, dairy farming just under 1 Mha and sheep farming around 0.83 Mha. Adult milking- and suckler-cow numbers were 1.56 and 0.92 million head, respectively, in 2020. Profitable tillage and dairy farms were typically on more productive land in the south and east of the country and represented 71% of farm income nationally (Teagsc 2023b). Beef and sheep farming are far less profitable, and in many cases non-viable from an economic perspective, predominating across the north and west of the country.

Agriculture contributed 38.5% of national greenhouse gas emissions in 2022 (EPA 2024a). The main sources were enteric fermentation from ruminant livestock (62%), $N_2O$ emissions from fertiliser application (19%) and manure management (12%). Average greenhouse gas emissions per hectare were 1.9 tonnes $CO_2$ eq. $ha^{-1}$ for tillage systems, 4.4 tonnes $CO_2$ eq. $ha^{-1}$ for beef systems and 9.4 tonnes $CO_2$ eq. $ha^{-1}$ for dairy systems (Teagasc 2023a). N surpluses range from 30 kg $ha^{-1}$ for sheep systems to 159kh $ha^{-1}$ for dairy systems.

CAP24 (DECC 2023) set out specific measures to reduce greenhouse gas emissions in agriculture and reach the 2030 emission reduction target of 25% compared to 2018. Some of these measures include changing how land is fertilised, improving the efficiency of livestock, expanding the organic sector, providing land use and farming diversification options and expanding the domestic biomethane industry. Improving the efficiency of livestock could inadvertently lead to an increased application of chemical fertiliser to grow feedstock at higher intensity. High-intensity grazing should be confined to existing improved agricultural grasslands and not extensively managed semi-natural grasslands.

#### *5.2.1.1 Fertiliser use and grazing*

CAP24 (DECC 2023) sets an ambitious target for greenhouse gas emissions related to synthetic fertilizer application, a reduction of chemical N use to a maximum of 300,000 tonnes and an increased adoption of inhibited urea, which reduces ammonia ($NH_3$) loss using a urease inhibitor (Forrestal *et al.* 2019). $N_2O$ emissions contribute significantly to greenhouse gas emissions in agriculture. Modelling as part of the Marginal Abatement Cost Curve modelling (Lanigan *et al.* 2023) describes different pathways (scenarios) related to more efficient and lower-emission N use which is also assessed in the Haughey *et al.* (2023b). CAP24 highlights the use of multi-species wards (MSS) and clover, improved slurry spreading systems and organic farming, but other measures are related to this and mentioned by Lanigan *et al.* (2023) e.g. soil liming and P corrections.

O'Brien *et al.* (2008) showed that the application of inorganic N fertiliser drives biodiversity loss and reduces water quality. To protect and enhance biodiversity and ecosystem services, N fertiliser input must be reduced.

Compared to single-species perennial ryegrass swards, MSS which comprises grass and legume species provides improved forage for livestock in terms of energy and protein. MSS with legume species reduces the need for chemical fertilisers (Moloney *et al.* 2021; Nyfeler *et al.* 2009), as legumes can fix and transfer N, increasing yield stability. MSS often supports a higher diversity of nematodes, a common indicator of soil food web complexity and soil health (Grace *et al.* 2019; Ikoyi *et al.* 2023; Nyfeler *et al.* 2024), and can also support a higher diversity of pollinators through increased floral resources and reduced chemical inputs (Malisch *et al.* 2024). The adoption of MSS as part of improved grassland systems will be positive for biodiversity if they replace monocultures and reduce the need for additional fertiliser. Using MSS are a means to reducing N fertiliser use, $N_2O$ emissions intensity (Cummins *et al.* 2021) and nitrate leaching (Nyfeler *et al.* 2024), they should not be considered as a replacement for semi-natural grasslands/High Nature Value farmland.

Grazing practices influence biodiversity. Reducing grazing (frequency) may not always lead to increases in biodiversity: it may increase sward height but not plant diversity. Also, high grazing pressure by sheep can cause significant degradation of upland heath, and cattle grazing on peatland is always likely to be detrimental. Grazing in upland areas has a higher carbon footprint relative to lowland intensive systems which should also be taken into account (Dawson *et al.* 2011). Stocking densities are another factor which impacts biodiversity, and reducing stocking densities has the potential to reduce greenhouse gas emissions. High stocking densities can have negative impacts on soil quality and sward, particularly in poor draining soil. Damage can be reduced by removing grazing livestock during heavy rain periods (Tuohy *et al.* 2013).

#### 5.2.1.2 Livestock and management practices

Changing livestock management practices also have the potential to reduce greenhouse gas emissions. CAP 24 (DECC 2023) targets include earlier finishing of beef cattle (3–3.5 months reduced finishing age), reduced age at first calving of suckler beef cows, improved animal breeding by focusing on low $CH_4$ traits, low emission animal feeding, including the addition of slow-release pasture-based feed additives/$CH_4$ inhibitors.

Increasing levels of concentrates in the diet of livestock can reduce $CH_4$ emissions, including through forage (Dawson *et al.* 2011; Waghorn & Clark 2006). Some additives have the potential to reduce N and P lost in excreta, as well as reducing $CH_4$, $NH_3$, and other noxious metabolic gases. Reducing $NH_3$ deposition by livestock to land or water will reduce the risk of eutrophication and acidification of ecosystems (Lewis *et al.* 2015), having positive impacts on biodiversity and water quality.

The origin of feed additives should be considered to ensure they are not causing biodiversity loss elsewhere and increasing emissions through transport.

#### 5.2.1.3 Diversify practices

Irish agriculture is currently dominated by dairy and livestock production, resulting in greenhouse gas emissions that are dominated by livestock-related $CH_4$ and $N_2O$ emissions. CAP24 (DECC 2023) lists diversification options that include changes in practices and land use (anaerobic digestion, forestry, tillage) as additional measures to reach greenhouse gas emission reduction targets.

Diversification may provide livestock farmers with alternative income avenues, and reduce emissions as a result of reduced stocking numbers. These could include a transition to conservation agriculture/organic farming, implementing multi-species swards, reducing chemical fertiliser, changes in livestock densities and grazing patterns, changes in feed additives, agroforestry, new cropping techniques, or shifting to food crop and horticultural production. Also, some of the agricultural land will need to be utilised to reach our renewable energy targets (see Section 5.1), and some land use will also have to transition to management that encourages carbon sequestration. CAP24 set a target of 450 kha of agricultural land to be converted to organic farming, an increase in tillage and horticulture to cover 400 kha and the inclusion of cover crops across 50 kha of tillage land.

#### 5.2.1.4 Soil and water table management

Overall, agricultural soils are a major source of greenhouse gas emissions owing to the drainage of large areas of organic soil under grass. However, some soils act as a carbon sink. Currently, sequestration of around 2 Mt $CO_2$ eq. in mineral soils under improved grassland offsets a portion of emissions arising from drainage of organic soils under grass (EPA 2024c).

Maintaining this sink through improved management of 450 kha of grasslands on mineral soils for carbon sequestration is a key target to improve the greenhouse gas balance in the LULUCF sector (DECC 2023). In tillage soils, the establishment of cover crops on 75 kha and incorporation of straw on 85 kha could each contribute enhanced carbon sequestration equivalent to 0.09 to 0.1 Mt $CO_2$ eq. $yr^{-1}$ by 2030.

CAP24 sets a target to reduce the management intensity and alter the water table level of at least 80 kha of grassland on drained organic soils by 2030. This target is based on the MACC pathway 2 measures (Lanigan *et al.* 2023) which assumes that the water table is raised to between 10-30 cm below the soil surface and that agricultural on drained organic soils cover an extensive area (about 339kha). Recently, Tuohy *et al.* (2023) estimated that only 90 kha (as opposed to 302 kha), of organic soil under grassland remains drained, as many drains have naturally blocked over time. Also, since there are no specific emission factors (EF) for reporting greenhouse gas emissions from rewetted agricultural soils, the EFs used are typically aggregate values for several land use types (Bianchi *et al.* 2021). Bianchi *et al.* (2021) also highlight that depending on the aim of rewetting (restoration or Paludiculture), different EFs may be required since the associated activities result in different greenhouse gas emission profiles.

Rewetting organic soils is an important measure to reach emission reduction and carbon balance targets. The continued productive use of wet or rewetted grassland, known as Paludiculture, is an important farming option and contributes to reducing greenhouse gas emissions from organic-rich soils. Studies on the biodiversity benefits of Paludiculture are limited (e.g. Martens *et al.,* 2023). Martens *et al.* (2023) showed that rewetted grassland (with water table management) provides biodiversity value, and that managed grassland had a higher plant diversity and, in their study, rare arthropods and breeding birds.

### 5.2.2 Wetlands

Organically rich peatlands are Ireland's most important carbon stock and require protection (DECC 2023). Peatlands are vulnerable and drainage or droughts can result in the oxidation of peat soil and turn them into sources of greenhouse gas emissions. In Ireland, wetlands refer to 'areas of peatland that have not been reported under another land use (i.e. forestry and grassland on organic soil) and that are either in a near-natural or some form of exploited status' (e.g. extraction of peat harvested for fuel and horticultural products) (EPA 2024d). The National Peatlands Strategy (NPWS 2015), suggests that peatlands in Ireland can be considered as 'humanised landscapes' (EPA 2024d) due to their extensive use and long-term exploitation. In Ireland, wetlands are a net greenhouse gas source. The 2022 National inventory report estimated that greenhouse gas emissions from wetlands cover an area of about 1.2 Mha, were 3.8 Mt $CO_2$ eq. (EPA 2024d).

CAP24 set two targets related to wetland emissions which are estimated to result in an additional greenhouse gas emission abatement of 1.3 Mt $CO_2$ eq. by 2030: continued restoration and rehabilitation of 35,900 ha of former peatland production lands and the rehabilitation of an additional 30 kha exploited peat rehabilitated (DECC 2023). This forms part of activities as part of Bord na Móna, Enhanced Decommissioning, Rehabilitation and Restoration Scheme (EDRRS) and LIFE People and Peatlands.

Rehabilitated peatland wetlands through rewetting have an increased ability to deliver ecosystem services, for example, enriched biodiversity, improved water quality and flood attenuation (DECC 2023). Kreyling *et al.* (2021) noted that because of peatland restoration through rewetting, the potential of peatlands to sequester carbon and N returns quickly; but the restoration of biodiversity can be delayed by decades. Renou-Wilson *et al.* (2019) noted that 'restoration implies the return of ecosystem services that were characteristic of the pre-disturbed ecosystem, achieving this goal is often a challenge in degraded peatlands as post-drainage conditions vary considerably between sites'. They recorded successes in terms of micro-habitat and species composition in a rewetted domestic cutover site, but species return to a rewetted industrially extracted peatland was more complex. According to them, rewetting shows greenhouse gas emissions reduction benefits more readily than for biodiversity.

### 5.2.3 Forestry

Forests with associated harvested wood products (HWP) are seen as important carbon stocks. Forests have a long-term carbon sequestration potential, but forest silvicultural practices and management greatly impact this (Jarmain *et al.* 2023). In 2022, the Forest land covering 0.78 Mha contributed to the removal of 1.5 Mt $CO_2$ eq. of greenhouse gas in Ireland; and an additional 0.9 Mt $CO_2$ eq. through HWP.

CAP24 sees afforestation as 'one of the largest land-based, long-term climate change mitigation measures available to Ireland' and has proposed several measures related to forestry to help aid in achieving the 2030 greenhouse gas emission reduction targets: e.g. afforestation (8,000 ha $yr^{-1}$), preventing deforestation (495 ha $yr^{-1}$), planting 2 kha of agroforestry; encourage the forest rotation cycle (max 31% of forests on suitable sites) and allow for forest replanting with birch on former afforested peats (max 18 kha) (DECC 2023).

Afforestation practices must comply with national laws to ensure sustainable management and environmental protection. Key legislation includes the Forestry Act 2014 (Irish Statute Book 2014), which regulates forest management, timber production, and afforestation. The EU Forestry Regulations 2017 (Irish Statute Book 2017) mandates environmental impact assessments for significant forestry projects to minimise ecological disruption and biodiversity loss, and the EU Renewable Energy Directive (EC 2021) directs that it is essential that forest bioenergy is produced sustainably. To do this, the Renewable Energy Directive introduced new sustainability criteria for biomass in heat and power, which covers forest biomass.

In Ireland, forestry including HWP is set to change from a greenhouse gas emissions sink to a net source of greenhouse gas emissions by 2028. This is due to the dynamics of forest harvests and replanting through time (change in the forest estate age) and also upwardly revised soil $CO_2$ emission factor for forestry planted on organic soils (EPA 2024d). Although CAP24 sets an afforestation of 8,000 ha $yr^{-1}$, Haughey *et al.* (2023b) and Styles *et al.* (2024) showed that achieving net zero greenhouse gas emissions by 2050 could require afforestation rates of 20,000 to 35,000 kha $yr^{-1}$ (with and without a separate split gas target for $CH_4$).

Afforestation with native woodlands can generate strong biodiversity benefits, alongside enhanced carbon storage in the land sector. But, fast-growing commercial plantations deliver a faster, stronger and potentially longer, climate mitigation effect, supporting downstream mitigation through carbon storage in wood products and displacement of greenhouse gas-intensive materials and energy (Forster *et al.* 2021).

Whilst afforestation will be critical for long-term climate targets, constrained rates of planting and slow growth in establishing forests means that this measure will not make a large contribution to 2030 targets. Rather, changes in the management of existing forests could play an important role up to 2030. The rotation interval has been reducing as more private forests reach harvestable age, and private landowners seek to realise investment (even if below the economic optimum age of harvest). This has the effect of reducing net carbon stock in forestry. According to CAP24, extending the rotation interval to the economic optimum across 31% of forests could deliver 0.89 Mt $CO_2$ eq. $yr^{-1}$ emission savings by 2030 (DECC 2023).

The influence of hedgerows on the greenhouse gas balance of the land sector is highly uncertain, ranging from being a small net source of $CO_2$ to a net sink of up to 1.4 Mt $CO_2$ $yr^{-1}$ (upper bound) (EPA 2024d). The lower bound reflects the net removal of hedgerows across the landscape and highlights the need for improved monitoring. In the best case, allowing hedgerows to grow wider and taller could increase carbon stock in standing biomass, but this effect will saturate in the medium term. So, whilst hedgerow management could be positive for both carbon and biodiversity, the carbon effect is limited. CAP24 includes a target for improved management across 75,000 km of hedgerows, and the establishment of 40,000 km of new hedgerows, to achieve abatement of 0.38 Mt $CO_2$ eq. $yr^{-1}$ by 2030. In addition, a target for the establishment of 2 kha of agroforestry also makes a small contribution to the LULUCF target of 4.6 Mt $CO_2$ eq. $yr^{-1}$ abatement by 2030 (EPA 2024d).

## 5.3 Impact assessment

### 5.3.1 Biodiversity objectives

The National Biodiversity Action Plan (NPWS 2024) lists several objectives and actions to meet urgent conservation and restoration needs in Ireland and is in support of the new EU restoration bill (EU 2024). Some of the objectives and actions will impact the measures Ireland has set in place to meet its carbon budget targets and hence have a climate change mitigation potential. These are summarised in Table 5-2 according to classes described in Table 5-1. Note: the objectives are from the National Biodiversity Action Plan (NPWS 2024); but, the potential biodiversity impact, climate mitigation potential, the impacts and mitigation measures listed are based on preliminary assessments and expert judgements by the project team. These are intended to highlight opportunities for co-delivery and trade-offs. Also, note that changes in greenhouse gas emissions, carbon sequestration and carbon stock all affect the carbon budget.

Table 5-2 shows that the actions in the National Biodiversity Action Plan are positive for biodiversity (light colour) and generally positive or neutral for the carbon balance. Biodiversity action generally protects carbon stocks (***), with mature ecosystems in carbon equilibrium providing a balance between greenhouse gas emissions (*) and carbon sequestration (**). Restoration actions on the other hand have the potential to provide a net reduction in greenhouse gas emissions as degraded ecosystems are restored to a carbon equilibrium state.

When considered together, as presented in Table 5-2, there is a tradeoff (≠) between carbon and biodiversity benefits which requires careful consideration specifically in terms of which areas should be targeted spatially across the landscape and Ireland. At present, there is considerable uncertainty in the climate change mitigation potential of different protection and restoration actions across ecosystems in Ireland.

*Table 5-1 Description of biodiversity impact potential and climate mitigation potential with their associated colour codes. This colour coding is applied to National Biodiversity Action Plan objectives in Table 5-2. Table 5-2 distinguishes climate mitigation potential n terms of reductions in greenhouse gas emissions (*), increases in carbon removals through sequestration (**), and/or protection of carbon stocks (***).*

| CODE | Biodiversity impact potential | Climate mitigation potential |
|---|---|---|
| | Positive (or neutral) impacts on biodiversity | Greenhouse gas emission reductions or active carbon sequestration |
| | Negative impacts on biodiversity that can be controlled/mitigated to maintain biodiversity | Maintain greenhouse gas emission sinks (no change in carbon stock) |
| | Negative impacts on biodiversity that cannot be reasonably controlled/mitigated to maintain biodiversity | Reduce carbon store |

*Table 5-2 A summary of National Biodiversity Action Plan objectives (NPWS 2024) and associated biodiversity impact potential and climate mitigation potential. Impacts and mitigation measures to address risks to biodiversity and climate actions are also listed. Note: the colour-coded potential biodiversity and climate mitigation potential, the impacts and mitigation measures listed are based on preliminary assessments and expert judgements by the project team. These are intended to highlight opportunities for co-delivery (++) and the risk of trade-offs (≠) between biodiversity and climate actions. Climate mitigation potential is distinguished in terms of greenhouse gas emissions (*), increased carbon removal through sequestration (**) and/or the protection of existing carbon stocks (***). Win-win (++) combinations to optimize are also shown; tradeoffs (≠) to consider carefully (where and how a mitigation measure is implemented) and lose-lose (--) combinations to avoid.*

| **Objective** | **Biodiversity impact potential** | **Climate mitigation potential** | **tradeoff ≠ lose-lose -- win-win ++** | **Impacts related to NBAP objectives and actions** | **Mitigation of risks to biodiversity and climate action** |
|---|---|---|---|---|---|
| 2A: Protection of existing designated areas, and protection of species is strengthened; conservation and restoration within the existing protected area network are enhanced | | **<br>*** | ≠ | -Protection, and conservation of important habitats, and bird species (threatened, endangered)<br>-Protection of important carbon stocks (e.g. peatlands)<br>-Enhanced protection of current agriculture, forest land, and other, for conservation | -Meaningful engagement with landowners/managers on assigned land for conservation<br>-Assessment to show benefits of conservation for habitats and species together with benefits or risks for greenhouse gas emissions, carbon sequestration and protection of carbon stocks. |
| 2B: Biodiversity, ecosystem services in the wider countryside are conserved and restored (agriculture & forestry) | | *<br>**<br>*** | ≠ | -Expand and protect habitat (conservation, protection areas), species (e.g. High Nature Value farming areas)<br>-Preserve landscape features (hedgerows, trees)<br>-Improve ecological connectivity (corridors)<br>-Farmers transition to organic farming, with associated productivity impacts<br>-Protect, restore on-farm biodiversity<br>-Expand on-farm biodiverse areas<br>-Reduction in chemical pesticide use, supporting biodiversity (plant, soil, water)<br>-Native tree species habitat support biodiversity, native bird species; resilient to pests, diseases<br>-Increase in pollinators and associated habitat<br>-Implement nature-based solutions (afforestation, conservation farming)<br>-Biodiversity is protected, restored in commercial forestry estate<br>-Increased planting of native trees in commercial forestry estate<br>-Protect carbon stock<br>-Reduce greenhouse gas emissions (pesticides, nitrates)<br>-Spatial distribution of carbon stock protected | -Support High Nature Value farming areas<br>-Support, expand results-based Agri Climate Rural Environment Scheme (ACRES)<br>-Farm Sustainability Plans<br>-Farm management plans to support connectivity<br>-Plan for impacts of increased organic farming<br>-Alternative measures, practices to combat pests and diseases and transition period<br>-Develop a national fire management plan<br>-Develop a deer management plan<br>-Illustrate benefits of native tree species for carbon, biodiversity<br>-Create a reliable supply of native tree species<br>-Promote (illustrate benefits of) nature-based solutions |

| Objective | Biodiversity impact potential | Climate mitigation potential | tradeoff ≠ lose-lose -- win-win ++ | Impacts related to NBAP objectives and actions | Mitigation of risks to biodiversity and climate action |
|---|---|---|---|---|---|
| | | | | -Reduction of nutrient (nitrates), pesticide runoff<br>-Improved water quality | |
| 2C: Biodiversity, ecosystem services in the wider countryside conserved and restored – (peatlands & climate action) | | *<br>**<br>*** | ≠ | -Protect peatland species, habitat<br>-Rehabilitate degraded peatlands<br>-Increase area under peatland<br>-Protect carbon stock (peatlands) | -Promote (illustrate benefits of) nature-based solutions<br>-Support, and incentivize peatland rewetting |
| 2D: Biodiversity, ecosystem services in marine, freshwater environment conserved and restored | | *** | ≠ | -Improve ecological status of water<br>-Increase in water bodies with High and Good ecological status<br>-Improve water quality<br>-Increase in aquatic species<br>-Sustainable use of water resources<br>-Reduction of N and phosphorous from fertilizers<br>-Reduction in pesticides, soil runoff<br>-River aquatic systems are protected<br>- Wetland habitat, species protection<br>-Conservation of marine biodiversity, ecosystem services<br>-Expanded marine conservation area<br>-Fish, shellfish stocks are protected<br>-Marine carbon stocks are protected<br>-Spatial distribution of carbon stocks maintained | -River basin management plan to protect water quality<br>-Measures to protect, enhance, monitor water status<br>-Measures to protect, restore high-status water bodies effectively<br>-Promote freshwater, transitional, coastal, marine nature-based solutions<br>-Promote terrestrial nature-based solutions<br>-Flood risk management plans<br>-Assess the impact of drainage on biodiversity of wetlands<br>-Measures to protect marine habitat, species, including combating illegal, unregulated fishing<br>-Measures to expand protected river length |
| 2H: Invasive alien species (IAS) controlled, managed on all-island basis to reduce harmful impact on biodiversity; measures undertaken to tackle introduction, spread of new IAS to environment | | *** | ≠ | -Existing IAS are removed<br>-Terrestrial Biodiversity (habitat, species) is protected<br>-Aquatic, marine diversity is protected<br>-Fire risk is reduced<br>-Removal of IAS may cause temporary carbon losses due to disturbances; reduction in carbon stocks from biomass removal | -Develop national Management Plan for IAS<br>-Control, manage and where possible and feasible, eradicate occurrences of invasive alien species<br>-Restoration to accompany IAS management to mitigate risks to carbon stores from disturbance and biomass removal |

### 5.3.2 Energy mitigation measures

To reach ambitious emission reduction targets, the Climate Action Plan (CAP 24) (DECC 2023) has set several energy objectives to reach by 2030 to transition away from fossil fuel burning and towards renewable energy.

Table 5-4 (according to criteria in Table 5-3) highlights the potential impacts the development of these renewable energy installations will have on biodiversity, which include habitat loss, fragmentation and degradation; species loss and disturbance; and loss of ecosystem services. All interventions included in Table 5-4 will have some form of carbon reduction potential, due to the production of renewable energy which does not release greenhouse gas emissions in comparison to fossil fuel burning.

While these interventions will have some negative impacts on biodiversity, there will also be positive impacts such as reducing air pollution and mitigating the effects of climate change. There is also a chance to implement mitigation measures along with these developments to enhance, protect and restore biodiversity in areas where these interventions occur. These measures are conveyed in Table 5-4. The interventions are based on the energy targets within CAP 24, and the risks to biodiversity from these interventions, along with mitigating measures to reduce these risks, based on published research i.e. Gorman *et al.* (2023), along with expert judgement from the project team.

Table 5-4 shows there is often a trade-off (≠) between the climate mitigation potential of a mitigation measure and its risk to biodiversity, but several mitigation measures have positive outcomes for both biodiversity and climate mitigation.

Co-benefit (++) example:

- Implementing an onshore wind energy installation on improved grassland would be beneficial for both biodiversity (light colour) and climate mitigation (light colour). Locating a development on an improved grassland would allow for biodiversity enhancement measures to be implemented locally and increase species diversity. The biodiversity benefits here may be smaller than for other interventions that present tradeoffs.

Tradeoff (≠) example:

- Growing feedstocks for biofuel in Protected Areas would have detrimental impacts on biodiversity (dark colour) but positive impacts on climate mitigation (light colour). Protected Areas should be avoided to minimise carbon losses through land use conversion as well as habitat and species loss. This signifies the importance of considering the intervention in the broader landscape, and where to appropriately locate it to maximise benefits for both biodiversity and climate.

*Table 5-3 Description of the risk to biodiversity and carbon emission reduction potential classes and their associated colour codes used to assess the impact of the energy mitigation measures proposed for Ireland as part of CAP24. Climate mitigation potential is distinguished in terms of greenhouse gas emissions (*), carbon emissions through sequestration (**) or carbon stocks (***).*

| CODE | Biodiversity Risk | Climate mitigation potential |
|---|---|---|
| | No or positive impacts on surrounding biodiversity | Net carbon removals. |
| | Negative impacts are balanced by positive outcomes for biodiversity. | |
| | Negative impacts can be easily controlled/mitigated to enhance biodiversity. | Carbon sequestration/carbon reduction depends on location; initial emissions but carbon sequestration/reduction in long-term. |
| | Negative impacts that require mitigation measures for biodiversity. If these cannot be implemented, land use change/development must be strictly managed. | |
| | Avoid land use change/development as negative impacts are too high/against legislation i.e. on PAs. | Limited carbon sequestration potential (Emit greenhouse gas from the landscape that is usually a carbon sink). |

*Table 5-4 Impact assessment of mitigation measures proposed for the energy sector in Ireland, specifically related to land use based on mitigation recommendations from Gorman et al. (2023). Note: the colour-coded biodiversity risk and climate mitigation potential, the impacts and mitigation measures listed are based on preliminary assessments and expert judgements by the authors. These are intended to highlight opportunities for co-delivery and trade-offs. Risks and potential are shown separately (where applicable) for different land uses like protected areas, organic-rich soils, improved grassland and semi-natural grassland. Colour codes are based on Table 5-3. Climate mitigation potential is separated in terms of reduction of greenhouse gas emissions (*), increased carbon removal through sequestration (**) and/or the protection of existing carbon stocks (***). Win-win (++) combinations to optimize are shown; tradeoffs (≠) to consider carefully (where and how a mitigation measure is implemented) and lose-lose (--) combinations to avoid.*

| Intervention | Risk to biodiversity | Climate mitigation potential | tradeoff ≠ lose-lose-- win-win ++ | Impacts | Mitigation of risks to biodiversity and climate actions |
|---|---|---|---|---|---|
| **Energy** | | | | | |
| Onshore wind | Protected Areas | * | ≠ | - Habitat loss<br>- Species loss and disturbance<br>- Degradation<br>- Fragmentation<br>- Disruption of carbon store<br>- Loss of essential ecosystem services | Avoid PAs, sensitive habitats and pristine peatlands where possible. If possible, avoid developments on natural carbon sinks. Implement biodiversity action plans, community engagement in biodiversity schemes (e.g. Nature+Energy project). New turbines or repowering only constructed on sites that minimise impacts on biodiversity. Site selection informed by existing PAs as well as functional connectivity and biodiversity sensitivity mapping. Include migration pathways, foraging routes in planning process. Co-locate with more intensive land uses. Monitoring to inform mitigation measures. |
| | Peatland (pristine) | * | -- | - Drainage<br>- Release of C<br>- Loss of protected and sensitive species<br>- Loss of essential ecosystem services | |
| | Peatland (degraded) | * | ≠ | - Species disturbance<br>- Further habitat loss and degradation | |
| | Improved grassland | * | ++ | - Habitat loss<br>- Species disturbance | |
| | Semi-natural grassland | * | ≠ | - Habitat loss<br>- Fragmentation<br>- Degradation<br>- Species disturbance and loss<br>- Release of C | |

| Intervention | Risk to biodiversity | Climate mitigation potential | tradeoff ≠ lose-lose-- win-win ++ | Impacts | Mitigation of risks to biodiversity and climate actions |
|---|---|---|---|---|---|
| | | | | - Loss of essential ecosystem services | |
| | Plantation forest (conifer) | * | ++ | - Release of C<br>- Species disturbance | |
| | Plantation forest (broadleaf) | * | ≠ | - Species disturbance<br>- Habitat loss<br>- Release of C | |
| | Native woodland | * | -- | - Release of C<br>- Habitat loss<br>- Species loss and disturbance<br>- Loss of essential ecosystem services | |
| Solar PV | Protected Areas | * | ≠ | - Habitat loss<br>- Species disturbance | Solar installations to be implemented on existing infrastructure where appropriate. Otherwise, improved agricultural pasture to be utilised where actions to enhance surrounding biodiversity is to be implemented:<br>- Restoration to semi-natural grasslands<br>- Hedgerow margins<br>- Wildflower buffer strips<br>Large-scale solar farms to avoid sensitive areas, minimise impact on biodiversity and put mitigation measures in place. Alternatives to herbicide to be used for vegetation management. |
| | Peatland (pristine) | * | -- | - Disturbance causing carbon emissions<br>- Disturbance of sensitive species<br>- Loss of essential ecosystem services | |
| | Peatland (degraded) | * | ++ | - Species disturbance | |
| | Improved grassland | * | ++ | - Species disturbance | |
| | Semi-natural grassland | * | ≠ | - Habitat loss<br>- Species loss and disturbance<br>- Loss of essential ecosystem services | |
| | Plantation forest (conifer) | * | ≠ | - Deforestation causing habitat loss, species disturbance, carbon emissions | |
| | Plantation forest (broadleaf) | * | ≠ | - Deforestation causing habitat loss, species disturbance, carbon emissions | |
| | Native woodland | * | -- | - Loss of specialist species<br>- habitat loss<br>- Loss of essential ecosystem services | |
| Offshore wind | Marine Protected Areas | * | ≠ | - loss of habitat<br>- species disturbance<br>- Loss of essential ecosystem services | Offshore wind should be avoided in MPAs. Mitigation measures could include artificial reefs for benthic species. Avoid foraging, calving, and migratory routes when deciding on a site. Construction during the low-risk season for sharks/whales/dolphins (when they are not migrating/foraging). Monitor area for these animals while construction ongoing, set speed limits for ships during construction and maintenance when animals present or likely to be present. Reduce underwater noise (Brooks 2019). Marine planning |
| | Migration paths | * | ≠ | - species disturbance | |
| | Sublittoral down to 60 m | * | ≠ | - habitat loss<br>- fragmentation<br>- degradation<br>- species disturbance | |
| | Shallow sublittoral | * | ≠ | - habitat loss<br>- fragmentation<br>- degradation<br>- species disturbance<br>- mortality | |

| Intervention | Risk to biodiversity | Climate mitigation potential | tradeoff ≠ lose-lose-- win-win ++ | Impacts | Mitigation of risks to biodiversity and climate actions |
|---|---|---|---|---|---|
| | | | | | strategies that include marine biodiversity protection and restoration. Further research on floating wind farm potential to minimise benthic disturbance. Exclusion zones to support recovery of stocks. If developed in bird migration pathway, alternative corridors between wind farms must be available. |
| Biofuel | Protected Areas | * | ≠ | - habitat loss<br>- species loss and disturbance<br>- fragmentation<br>- Carbon store disruption<br>- Loss of essential ecosystem services | Feedstock for livestock and planting for biofuel should be implemented on existing improved agricultural land, so as not to lead to increase in intensity and increased application of chemical fertilizer to grow feedstock and to minimise carbon losses. Avoid PAs and semi-natural areas. Prioritise waste products for biofuel. Protection of important landscape features where land use change to biofuel crops occur e.g. hedgerows, ponds, buffer strips.<br>Explore nature-friendly farming management (e.g. infrequent mowing) as feedstock for Anaerobic Digestion. |
| | Improved grassland | * | ++ | - species disturbance | |
| | Semi-natural grassland | * | ≠ | - habitat loss<br>- species loss and disturbance<br>- fragmentation<br>- degradation<br>- Carbon store disruption<br>- Loss of essential ecosystem services | |

## 5.3.3 Agriculture, Forestry and Land Use mitigation measures

‘Nature-based solutions’ (Nbs) or ‘Natural climate solutions’ (NCS) use conservation and ecosystem management to reduce greenhouse gas emissions and increase carbon storage, along with enhancing climate adaptation features. Nature-based solutions are often highlighted as part of the answer to the climate change problem, but Seddon *et al.* (2021) stress that nature-based solutions should be biodiversity-positive and should not include actions that exploit nature, damage biodiversity or harm sensitive species. Land utilisation can drive biodiversity loss (IPBES 2019) through habitat fragmentation, loss, and degradation, but can also present solutions. Seddon *et al.* (2021) note that there is an overemphasis on certain nature-based solutions like afforestation which can be harmful if implemented inappropriately (e.g. carbon-rich soils, open habitats) which will lead to a tradeoff in ecosystem services. They highlight biodiversity-positive nature-based solutions like agroforestry and types of afforestation that support native tree revegetation in degraded areas or that remove pressure from native forests. Other biodiversity-negative nature-based solutions include exotic tree plantations that replace intact native ecosystems (ancient grasslands, peatlands) or plantation species that become invasive.

CAP24 (DECC 2023) proposes several mitigation measures to reduce greenhouse gas emissions, protect carbon stock or increase carbon sequestration in the Agriculture Forestry Land Use sector. These are also discussed by Haughey *et al.* (2023) and Lanigan *et al.* (2023) who provide details on modelling scenarios to assess their impacts. Each of these measures has either co-benefits or trade-offs with biodiversity potential. For forestry, measures include e.g. increasing afforestation and planting of new hedgerows; for wetlands, rehabilitation and rewetting of peatlands; for croplands, the adoption of different cultivation practices; and for grassland, optimising or reducing intensive management of grasslands. Haughey *et al.* (2023a) also provide a basic assessment of the impact of these proposed measures on climate mitigation, biodiversity and water quality and its extent.

Table 5-6 and Table 5-7 (according to criteria in Table 5-5) provide an overview of the impact of proposed mitigation measures on LULUCF, and agriculture, respectively. Note: the measures are from the CAP24 (DECC 2023); but, the risk to biodiversity, climate change mitigation potential, and the impacts and mitigation measures listed are based on preliminary assessments and expert judgements by the project team. These are intended to highlight opportunities for co-delivery and trade-offs. It is important to note that the exact risk to biodiversity and climate mitigation potential will depend on the implementation of the mitigation measure (what a measure replaces, where a measure is implemented and how). Table 5-6 and Table 5-7 are intended as a starting point for discussions on co-benefits and trade-offs.

Table 5-6 shows that for LULUCF, there is almost always a trade-off (≠) between the climate mitigation potential of a mitigation measure and its risk to biodiversity when a specific plot of land is considered. This highlights the fact that this climate mitigation-biodiversity interrelationship is complex and conditions-specific: plot or field condition, spatial location and implementation practices. Tools to help optimise the trade-offs are needed.

Co-benefit (++) example:

- Increasing cover crops in tillage land will be beneficial for biodiversity (light colour) and as a climate mitigation measure (light colour). The carbon and biodiversity benefits may be smaller than for measures that present tradeoffs.

Tradeoff (≠) example:

- The benefits of afforestation to climate mitigation and biodiversity depend on the exact conditions, but often present tradeoffs (≠). Afforestation needs to be considered broadly in the landscape and regionally together with afforestation practices (silviculture). E.g. if protected areas or semi-natural grasslands are afforested or a landscape is dominated by an exotic conifer monoculture and managed only for maximum productivity, then afforestation will be detrimental to biodiversity. Also, if organic-rich soils are afforested it will be detrimental to climate mitigation due to carbon stock losses from disturbances. But if new forests are carefully sited, a mix of species across the landscape used and forest management is implemented to promote a range of ecosystem services and biodiversity-friendly practices, then afforestation may be beneficial to biodiversity.

*Table 5-5 Description of the risk to biodiversity and climate mitigation potential criteria and the associated colour codes to evaluate the impact of the proposed climate mitigation measures for LULUCF, and Agriculture as part of CAP24. In Table 5-6 and Table 5-7, climate mitigation potential is distinguished in terms of reductions in greenhouse gas emissions, and increased carbon removals through sequestration and/or protection of carbon stocks.*

| CODE | Risk to Biodiversity | Climate mitigation potential |
|---|---|---|
| | Positive or neutral impacts on surrounding biodiversity | Greenhouse gas emission reductions (sink) |
| | Negative impacts are balanced by positive outcomes for biodiversity. | |
| | Negative impacts can be easily controlled/mitigated to enhance biodiversity. | Maintain greenhouse gas emission sinks (no change in emissions, carbon stock) |
| | Negative impacts that require mitigation measures for biodiversity. If these cannot be implemented, land use change/development must be strictly managed. | |
| | Avoid land use change/development as negative impacts are too high/against legislation i.e. on PAs. | Reduce carbon stock (emissions source) |

*Table 5-6 Overview of the risk to biodiversity and climate mitigation potential linked to individual carbon budget mitigation measures for LULUCF. Note: the colour-coded risk biodiversity and climate mitigation potential, and the impacts and mitigation measures listed are based on preliminary assessments and expert judgements by the project team. These are intended to highlight opportunities for co-delivery and trade-offs. Risks and potential are shown separately (where applicable) for different land uses like protected areas, organic-rich soils, improved grassland and semi-natural grassland. Colour codes are based on Table 5-5. Climate mitigation potential is separated in terms of greenhouse gas emissions (*), increased carbon removal through sequestration (**) and/or the protection of existing carbon stocks (***). Win-win (++) combinations to optimize are shown; tradeoffs (≠) where careful consideration should be given to where and how a mitigation measure is implemented; and lose-lose (--) combinations to avoid.*

| Intervention | Biodiversity Risk | Climate mitigation potential | tradeoff ≠ lose-lose -- win-win ++ | Impacts related to CAP24 mitigation measures | Mitigation of risks to biodiversity and climate action |
|---|---|---|---|---|---|
| **FORESTRY** | | | | | |
| Afforestation (Conifer dominated) | Organic-rich soils | ** *** | ≠ | -Habitat, species loss due to monoculture<br>-New tree habitat creation<br>-Change soil microbial biodiversity<br>-Impact on soil pH, water quality | -Low-impact siting important (landscape, regional)<br>-Avoid high nature value sites<br>-Beneficial species (indigenous conifer species), species mix encouraged<br>-Smart Forestry practices encouraged |
| | Improved grassland | * ** | ≠ | | |

| Intervention | Biodiversity Risk | Climate mitigation potential | tradeoff ≠ lose-lose -- win-win ++ | Impacts related to CAP24 mitigation measures | Mitigation of risks to biodiversity and climate action |
|---|---|---|---|---|---|
| | Protected areas | *<br>** | ≠ | -Long-term carbon sequestration potential (trees, HWP)<br>- Greenhouse gas emissions due to disturbances (planting, management, harvesting)<br>-Different ecological services (wood, fruits, shelter)<br>-Susceptibility to pests and diseases<br>-Susceptibility to fire | -Afforestation on organic-rich soils discouraged<br>-Low-impact management, harvesting<br>-Extend rotation<br>-Diversify forest structure<br>-Spatial distribution over landscape<br>(mosaic)<br>-Buffer zones, and corridors to enhance biodiversity<br>-Management of risks (pests, diseases, fire) |
| | Semi-natural grassland | *<br>** | ≠ | | |
| Afforestation (Broadleaf) | Protected areas<br>Organic-rich soils<br>Semi-natural grassland | *<br>**<br>*** | -- | -Current habitat, species loss<br>-New tree habitat creation (for birds, invertebrates etc.)<br>-Increase soil microbial biodiversity<br>-Impact on water quality<br>-Long-term carbon sequestration potential (trees, HWP)<br>-Ecological services (wood, fruits, shelter)<br>- Greenhouse gas emissions due to disturbances (planting, management, harvesting)<br>-Diversification of forest land spatially | -Avoid high nature value sites<br>-Low-impact siting important<br>-Restore, and reforest native woodlands where possible<br>-Beneficial species<br>-Smart Forestry<br>-Afforestation on organic-rich soils discouraged<br>-Low-impact management, harvesting<br>-Extend rotation<br>-Spatial distribution over landscape<br>(mosaic)<br>-Buffer zones, and corridors to enhance biodiversity |
| | Improved grassland | ** | ≠ | | |
| Agroforestry | Protected areas<br>Organic-rich soils<br>Semi-natural grassland | *<br>**<br>*** | -- | -Increase habitat, species heterogeneity, biodiversity (birds, pollinators)<br>-Increase soil microbial biodiversity<br>- Greenhouse gas emissions due to disturbances (planting, management, harvesting)<br>-Microclimate regulation<br>-Enhanced nutrient cycling<br>-Diversification of land use spatially | -Avoid protected areas and high nature value sites<br>-Create buffer zones, corridors<br>-Prioritize native, complimentary, diversity of species<br>-Siting agroforestry fields<br>-Low-impact practices<br>-Avoid deep tillage (protected, organic-rich soils)<br>-Use mulches, and compost to enhance carbon in soil<br>-Grazing (rotation) management beneficial to grass and trees<br>-Use trees to improve soil |
| | Improved grassland | **<br>*** | ≠ | | |
| Extend forestry rotation (conifer) | Organic-rich soils | *<br>**<br>*** | -- | -Sustained habitat, biodiversity (poor or good)<br>-Limited biodiversity benefits for monocultures<br>-Increased biomass, carbon sequestration, long-term carbon stock (trees, HWP)<br>-Delayed availability of HWP<br>-Reduced harvest disturbance<br>-Increased susceptibility of trees to pests, diseases<br>-Not beneficial to species thriving in young forests | -Extending MMAI on organic-rich soils discouraged<br>-Low-impact management, harvesting practices<br>(continuous cover forestry)<br>-Enhance soil carbon by leaving harvest residues<br>-National forest age planning for sustained harvest<br>-Planning for pests, disease and fire (increased litter)<br>-Diversify species or create mixed-species plantations<br>-Design for diverse habitats<br>-Manage rotation length to benefit important species |
| | Mineral soil | *<br>** | ≠ | | |

| Intervention | Biodiversity Risk | Climate mitigation potential | tradeoff ≠ lose-lose -- win-win ++ | Impacts related to CAP24 mitigation measures | Mitigation of risks to biodiversity and climate action |
|---|---|---|---|---|---|
| Prevent deforestation | Protected areas Organic-rich soils | *<br>**<br>*** | ≠ | -Maintained carbon store, sequestration, protection<br>-Habitat protection<br>-Biodiversity conditions maintained | - Allow conversion if existing forest is detrimental to C, biodiversity<br>-Allow conversion of organically rich soils, where beneficial<br>-Low-impact management, harvesting |
| | Mineral soils | *<br>**<br>*** | ≠ | | |
| Convert (replant) existing organic soil forests to birch | Protected areas Organic-rich soils | *<br>**<br>*** | ≠ | -Diversification of forest land spatially<br>-Long-term carbon stock, mitigation potential<br>-Establishment losses (species, habitat, biodiversity, C)<br>- Biodiversity-rich new understory<br>-Support native species (habitat)<br>-Improved soil structure in degraded land | -For organic-rich peatlands, consider rewetting<br>-Consider gradual conversion to allow dependent species to adapt<br>-Identify and protect important species (protection zones)<br>-Low-impact management<br>-Develop a forest management plan to address risks |
| | Mineral soils | *<br>**<br>*** | ≠ | | |
| Plant, improve hedgerows | Protected areas Organic-rich soils Semi-natural grassland | *<br>**<br>*** | ++ | -Increased carbon sequestration, stock potential (biomass, soil)<br>-New microclimate (wind, frost protection)<br>-Increase, and diversify habitat, biodiversity<br>-Establishment disturbances<br>-Management disturbances<br>-Ecological corridor creation<br>-Floral diversity<br>-Land use diversification | -Avoid planting in protected areas, on organic-rich soil unless part of a larger restoration plan<br>-Ensure that hedgerows do not impact existing important species, habitat<br>-Plant native, beneficial species, and/or species mixes (complementary, compatible, diverse) species<br>-Establish buffer zones<br>-Avoid hedge cutting over sensitive periods<br>-Apply sustainable management practices (trimming, etc.)-Design hedgerows for an optimum, range of benefits |
| | Improved grassland | *<br>**<br>*** | ++ | | |
| **CROPLAND** | | | | | |
| Increase cover crops | Tillage land | *<br>** | ++<br>≠ | -Increase in soil C, carbon sequestration (long-term)<br>-Improved soil structure<br>-Reduced erosion<br>-New habitat for soil organisms<br>-Increased above-ground biodiversity, bird and wildlife habitat<br>-Weed suppression (reduce herbicide use)<br>-Reduce the need for chemical N<br>-Establishment impact (carbon losses) | -Select suited, beneficial, cover crop species<br>-Use a mixture of species, including flowering species<br>-Implement no-tillage or reduced-tillage practices<br>-Adopt long-term view for benefits<br>-Consider timing of the establishment<br>-Create corridors for habitat connectivity<br>-Implement cover crop rotation<br>-Integrative pest management<br>-Integrated nutrient management |
| Increase straw incorporation | Cereal crop area | *<br>** | ++ | -Increase in soil C, carbon sequestration (long-term) | -Consider timing of straw incorporation to maximise decomposition, benefits |

| Intervention | Biodiversity Risk | Climate mitigation potential | tradeoff ≠ lose-lose -- win-win ++ | Impacts related to CAP24 mitigation measures | Mitigation of risks to biodiversity and climate action |
|---|---|---|---|---|---|
| | | | ≠ | -Improved soil structure, fertility<br>-Reduced erosion<br>-Initial decomposition releasing $CO_2$<br>-Increased microbial activity<br>-Improved habitat, food for soil organism<br>-Diversify soil microbes<br>-Unmanaged straw incorporation could benefit pests, diseases<br>-Potential from certain types of material to negatively impact subsequent crop growth (Allelopathy)<br>-Reduce need for chemical N | -Adequate incorporation of straw to benefit erosion protection, decomposition<br>-Combine with reduced tillage<br>-Diversify crop rotations for maximum benefits and to prevent negative allelopathic effects<br>-Introduce, promote beneficial micro-organisms that can aid in straw decomposition<br>-Integrate in balanced nutrient management plan |
| Increase manure use on cropland | Cropland | *<br>** | ++<br>≠ | -Reduce need for chemical N<br>-Use of available N source<br>-Increased microbial activity in soil<br>-Increased diversity, activity of soil organism<br>-Potential for $CH_4$, $N_2O$ emissions if unmanaged<br>-Potential for initial Greenhouse gas emissions (decomposition), offsetting carbon sequestration benefits in the short term<br>-Potential for weed introduction<br>-Potential for nutrient runoff, water pollution<br>-Potential introduction of pathogens, heavy metals | -Develop a nutrient management plan<br>-Optimise application rate (timing, amount) to avoid over-application<br>-Incorporate manure into the soil (prevent volatilization of ammonia)<br>-Apply when crop uptake is high<br>-Test soil to monitor soil nutrients<br>-Combine with cover crops to optimize its use<br>-Monitor and manage weeds<br>-Create buffer zones to protect water bodies<br>-Only incorporate adequately composted/treated manure to reduce pathogen, heavy metal loads |
| **GRASSLAND** | | | | | |
| Improve grassland management[#] (mineral soil) | Improved grassland Semi-natural grassland | *<br>** | ++ | -Increased biomass production (above and below ground), soil carbon<br>-Reduced soil disturbances<br>-Enhanced (diverse) biodiversity, habitat, and food source in diverse grasslands<br>-Diverse soil microbial communities<br>-Improved ecosystem health<br>-Protection of carbon store<br>-Increased grass production (quantity, quality)<br>-Reduced fertilizer application<br>-Reduced nutrient losses<br>-Water quality protection/improvement | -Optimise management practices<br>-Introduce, optimize rotation grazing<br>-Introduce optimal species selection, composition (e.g. mix of deep-rooted perennial grasses and legumes)<br>-Encourage use of a diverse mix of species<br>-Monitor, manage stocking rates to prevent overgrazing<br>-Reduce soil disturbance (plowing, etc.)<br>-Introduce habitat features (ponds, hedgerows) for additional benefits<br>-Identify, protect sensitive areas (riparian zones) |

| Intervention | Biodiversity Risk | Climate mitigation potential | tradeoff ≠ lose-lose -- win-win ++ | Impacts related to CAP24 mitigation measures | Mitigation of risks to biodiversity and climate action |
|---|---|---|---|---|---|
| Reduce grassland management (drained organic soil) | Improved grassland<br>Semi-natural grassland | *<br>**<br>*** | ++ | -Reduced $CO_2$ emissions<br>-Initial decrease in productivity<br>-Habitat restoration<br>-Recovery of native species<br>-Increased plant species, structural diversity<br>-Short-term wildlife habitat shifts, population changes | -Where possible, rewet organic soil and reduce $CO_2$ emissions<br>-Optimise management practices<br>-Adopt minimum disturbance practices<br>-Reintroduce, promote growth of native species<br>-Promote natural succession of species<br>-Monitor and control invasive species<br>-Create buffer zones to protect water quality, sensitive areas<br>-Maintain a mosaic of habitats (heterogeneity) |
| **WETLAND** | | | | | |
| Rehabilitate peatlands | Bord na Móna extraction peatlands | *<br>*** | ++ | -Reducing Greenhouse gas emissions<br>-Protect large carbon store<br>-Habitat restoration of often rare, endangered species<br>-Enhanced plant diversity (native species like Sphagnum mosses)<br>-Restored habitat for wildlife (birds, insects, amphibians)<br>-Improved water quality | -Rewet peatlands<br>-Long-term plan<br>-Optimise rehabilitation<br>-Actively reintroduce native species, Sphagnum mosses<br>-Reduce, minimize disturbances<br>-Monitor, control invasive species<br>-Create habitat diversity (microhabitats)<br>-Create buffer zones to protect peatland, adjacent productive land |
| Rewet additional peatlands | Protected areas<br>Grassland (improved, semi-natural)<br>Organic-rich soil | *<br>*** | ++ | -Reducing Greenhouse gas emissions<br>-protect large carbon store<br>-Habitat restoration of often rare, endangered species<br>-Enhanced plant diversity<br>-Restored habitat for wildlife (birds, insects, amphibians)<br>-Improved water quality<br>-Increase landscape diversity | -Optimise selection of fields for the biggest impact<br>-Re-establish natural water levels by blocking drainage channels and ditches<br>-Actively reintroduce native species<br>-Reduce, minimize disturbances (drainage, peatland extraction, grazing)<br>-Monitor, control invasive species<br>-Create habitat diversity (microhabitats)<br>-Create buffer zones to protect peatland, adjacent productive areas |

According to CAP24 (DECC 2023), key mitigation measures for agriculture include an increased production efficiency, a reduction in chemical N use and the subsequent increased adoption/use of inhibited urea, and measures to reduce emissions related to livestock. See also the basic assessment by Haughey *et al.* (2023a) of these measures on climate mitigation, biodiversity and water quality and their extent, and the recent scenario modelling assessment considering these measures (Styles *et al.* 2024).

Table 5-7 (per criteria in Table 5-5) shows our assessment of the impact of mitigation measures for agriculture on biodiversity (risk) and climate mitigation (potential). It shows that the proposed climate mitigation measures often present trade-offs between biodiversity and climate mitigation. For such cases, the exact impact (risks and potential) will depend on the implementation of the mitigation measure: where in a region or landscape, the properties of the field or plot of land and how the measures are implemented.

Co-benefits (++) example for agriculture:

- Measures like changing slurry applications or changing to organic farming are positive for climate mitigation (light colour) and biodiversity (light colour), but the size of the benefits (colour shading) will differ between the exact conditions.

Tradeoffs (≠) example for agriculture:

- Reducing the finishing age of livestock (bovine) is positive (light colour) for climate mitigation but could be negative for biodiversity (range in darker colour shades). Reducing the finishing age could result in more intensive grazing or faster grazing cycles which could lead to less plant diversity, a degraded habitat and soil compaction, all impacting biodiversity negatively. Rotational grazing or exclusion grazing periods or zones are measures that can lessen the impact.

*Table 5-7 Overview of the risk to biodiversity and climate mitigation potential linked to individual carbon budget mitigation measures for agriculture. Note: the colour-coded biodiversity risk and climate mitigation potential, and the impacts and mitigation measures listed are based on preliminary assessments and expert judgements by the project team. These are intended to highlight opportunities for co-delivery and trade-offs. Risks and potential are shown separately (where applicable) for different land uses like protected areas, organic-rich soils, improved grassland and semi-natural grassland. Colour codes are based on Table 5-5. Climate mitigation potential is separated in terms of greenhouse gas emissions (*), increased carbon removal through sequestration (**) and/or the protection of existing carbon stocks (***). Win-win (++) combinations to optimize are shown; tradeoffs (≠) to consider carefully where and how a mitigation measure is implemented and lose-lose (– ) combinations to avoid.*

| **Intervention** | **Biodiversity Risk** | **Climate mitigation potential** | **tradeoff ≠ lose-lose -- win-win ++** | **Impacts related to CAP24 mitigation measures** | **Mitigation of risks to biodiversity and climate action** |
|---|---|---|---|---|---|
| **LIVESTOCK** | | | | | |
| Reduced Finishing Age (Bovine) | Semi-natural grassland | * | ≠ -- | -Increased intensity of grazing<br>-Reduced overall greenhouse gas ($CH_4$) emissions per animal<br>-Increased production efficiency<br>-Soil compaction, disturbance with more intensive grazing | -Monitor and adjust grazing capacity to prevent overgrazing, maintain plant diversity<br>-Rotational grazing<br>-Create grazing exclusion (limiting) zones to protect sensitive areas<br>-Minimize soil compaction, disturbances |
| | Improved grassland | * | ≠ -- | | |

| Intervention | Biodiversity Risk | Climate mitigation potential | tradeoff ≠ lose-lose -- win-win ++ | Impacts related to CAP24 mitigation measures | Mitigation of risks to biodiversity and climate action |
|---|---|---|---|---|---|
| | Protected areas | *<br>*** | ≠<br>-- | -Change in vegetation, biodiversity species with fast grazing cycles<br>-Overgrazing risk, with less plant diversity, degrading habitat<br>-Nutrient imbalances, less grass growth due to heavy grazing | -Use organic soil amendments<br>-Promote native species that support wildlife, ecosystem resilience<br>-Avoid grazing in unfavourable conditions (very wet conditions) |
| Extend grazing season | Semi-natural grassland | *<br>*** | ≠ | - Reducing overall greenhouse gas ($CH_4$) emissions (more grass, less silage)<br>-Soil compaction due to extended grazing pressure, especially under wet conditions<br>-Overgrazing under poor management (reduced biomass, carbon sequestration)<br>-Degradation when poorly managed<br>-Susceptibility to invasive species when poorly managed<br>-Under Intensive management, grazing improved grasslands favour few species, reducing diversity<br>-Habitat degradation, species loss under overgrazing | -Grazing management to avoid overgrazing<br>-Rotational grazing<br>-Grass rest periods for plant recovery and to increase soil C<br>-Avoid grazing under unfavourable conditions (very wet conditions)<br>-Establish buffer zones to protect sensitive areas<br>-Promote native species through reseeding, controlled grazing<br>-In improved grassland, use precision fertilizer application (optimal nutrient use, reduced nutrient runoff)<br>-In protected areas, use low-impact grazing; restrict the grazing season; create buffer zones around sensitive areas |
| | Improved grassland | *<br>*** | ++<br>≠ | | |
| | Protected areas | *<br>*** | ≠ | | |
| Change in livestock diet (feed additives, concentrate intake, protein content of concentrate) | | * | ++ | -Change in grazing<br>-Change in excrement and urine-related emissions, pollution | -Optimise grazing management<br>-Reduce concentrate intake and crude protein content of concentrate<br>-Increase unsaturated fatty acids (lipids)<br>-Avoid grazing in protected areas |
| Reduce Livestock numbers (bovine: ovine) | Semi-natural grassland<br>Improved grassland | * | ++ | -Reduction in greenhouse gas emissions, nutrient leaching<br>-Under grazing in semi-natural High Nature Value grassland may cause shrub encroachment<br>-Impact grassland species diversity<br>-Reduced pressure on sensitive habitats<br>-Under grazing may increase risk of invasive species<br>-Vegetation recovery under lower numbers | -Determine optimal livestock rate and composition<br>-Management to prevent overgrazing, under grazing, invasive species, maintain grassland species diversity<br>-Use (optimal, rotational) grazing to enhance soil carbon and protect the soil<br>-Manage manure input for improved soil health, soil structure, soil C, prevent nutrient imbalances<br>-Buffer zones around sensitive areas<br>-For protected areas: low to moderate numbers balance<br>-Limit grazing season |
| | Protected areas | * | ≠ | | |
| **GRASSLAND, CROPLAND** | | | | | |
| Apply (Use of) Digestate | *<br>** | * | ≠ | -Greenhouse gas ($CH_4$) emissions from incorrect application, storage | -Develop, implement nutrient management plan to avoid over-application, minimize leaching |

| Intervention | Biodiversity Risk | Climate mitigation potential | tradeoff ≠ lose-lose –– win-win ++ | Impacts related to CAP24 mitigation measures | Mitigation of risks to biodiversity and climate action |
|---|---|---|---|---|---|
| | | | | -Excessive application can affect plant, microbial diversity, nutrient runoff<br>-Use of available byproduct<br>-Reduced use of chemical fertilizer<br>-Increased microbial activity, soil health, nutrient cycling | -Application during growing season from maximum uptake<br>-Use application methods that reduce ammonia volatilization, nutrient runoff<br>-Establish buffer zones to protect water bodies from pollution |
| Clover, multi-species swards, legumes** | Protected areas | * | ≠ | -Increase C losses due to disturbances (plough, plant) when replacing semi-natural grassland, protected land<br>-Reduced fertilizer use (legumes)<br>-MSS provide increased species diversity, habitat<br>-Enhanced plant growth due to improved soil fertility (long-term)<br>-Improve soil C, soil structure<br>-Ecosystem more resilient to pests, diseases<br>-Potential overgrowth where species dominate | -Careful species selection to complement existing species, prevent species dominance, overgrowth, prioritise native species<br>-Careful, gradual introduction to provide the most ecosystem benefit<br>-Balanced nutrient management<br>-Integrated pest management<br>-Adaptive management<br>-Rotational grazing |
| | Improved grassland | *<br>** | ≠ | | |
| | Semi-natural grassland | *<br>** | ≠ | | |
| Fertilizer formulation (protected urea, low nitrate compounds) | Semi-natural grassland Protected areas | * | ≠ | -Reduced greenhouse gas emissions<br>-Improve health of ecosystems (species, habitat)<br>-Reduced nitrate runoff, improved water quality, protect aquatic species<br>-Over-application will negatively impact plant diversity, habitat<br>-Short-term impact on sensitive species (transition period)<br>-Risk of nutrient imbalance (crops) | -Nutrient management plans, monitoring<br>-Use appropriate nutrient formulations to avoid imbalances<br>-Avoid excessive fertilizer application<br>-Implement practices to actively promote biodiversity<br>-Buffer zones to protect sensitive areas |
| | Improved grassland | * | ≠ | | |
| | Croplands | * | ≠<br>++ | | |
| Changes in slurry application (Low Emission Slurry Spreading, Slurry amendments, acidification, Slurry aeration) | Semi-natural grasslands | * | ≠ | -Lower greenhouse gas emissions ($CH_4$, $N_2O$)<br>-Use available nutrient sources<br>-Reduced runoff, impact on water quality<br>-Risk of nutrient imbalances<br>-Cropland and its soil biota require time to adjust to new fertilizer<br>-Initial disturbance, impact on sensitive species<br>-Incorrect slurry application may lead to nutrient runoff, soil and water impacts | -Integrated nutrient management<br>-Site-specific slurry application practices for semi-natural grassland<br>-Soil nutrient, plant monitoring<br>-Application (techniques) to benefit native species, protect sensitive habitats<br>-Gradual implementation<br>-Avoid over-application<br>-Avoid, and protect sensitive areas through buffer zones<br>-Plan for adaptation period<br>-Create buffer zones to protect sensitive areas, water bodies |
| | Improved grassland Cropland | * | ++ | | |
| Organic farming | Semi-natural grassland | *<br>**<br>*** | ≠ | -Benefits depend on management choice<br>-Reduced chemical fertilizer, pesticide use and associated greenhouse gas emissions<br>-Improved soil health | -Site-specific management<br>-Promote native species<br>-Measure to maintain soil fertility using organic amendments, crop rotation |

| Intervention | Biodiversity Risk | Climate mitigation potential | tradeoff ≠ lose-lose -- win-win ++ | Impacts related to CAP24 mitigation measures | Mitigation of risks to biodiversity and climate action |
|---|---|---|---|---|---|
| | | | | -Increased plant diversity<br>-Initial yield reductions<br>-Initial pest management challenges<br>-Management to avoid overgrazing<br>-More pollinators | -Gradual transition that allows ecosystems to adapt<br>-Monitor ecosystem health |
| | Improved grassland | * | ++ | -Reduced chemical dependency (fertilizer, pesticide)<br>-Reduce emission from synthetic fertilizer, disturbances<br>-Long-term increased soil organic matter<br>-Weed and pest control challenges<br>-Potential for overgrazing<br>-More pollinators | -Gradual transition that allows ecosystems to adapt<br>-Integrated nutrient, land, biodiversity management<br>-Soil and plant monitoring |
| | Cropland | * | ++ | -Reduced chemical dependency (fertilizer, pesticide) and related emissions<br>-Reduced C losses from disturbances<br>-Yield variability<br>-Long-term enhanced soil health, soil biota<br>-More pollinators<br>-Reduction in fertilizer leaching, pesticides<br>-Improved water quality | -Crop rotations to support soil health<br>-Use organic amendments<br>-Implement conservation practices (minimum, no-tillage, cover crops)<br>-Management to maintain soil fertility, control pests |
| | Livestock | * | ≠<br>++ | -Reduced emissions from synthetic fertilizer<br>-Nutrient management, production challenges<br>-Improved animal welfare<br>-Enhanced habitat quality, diversity (long-term)<br>-Risk of overgrazing | -Organic feed<br>-Rotational grazing<br>-Biodiversity-friendly practices<br>-Planning, monitoring and adaptation<br>-Encourage hedgerows, and buffer zones to improve biodiversity |

# 6 Conclusion and recommendations

This research concludes that to achieve emission reduction targets whilst protecting biodiversity, Ireland will need to reach compromises involving demand management and resource use, along with systemic societal changes in energy demand, consumption, and waste. Several conclusions are presented below which are expanded on in the key recommendations listed in Table 6-1.

- Statutory obligations for biodiversity protection and restoration must be implemented, with co-benefits for the protection of carbon stocks, reduction of greenhouse gas emissions and carbon removals through biological sequestration quantified. Policies which deal with land use should be aligned to achieve climate and biodiversity obligations.

- National land use strategy should be developed that explicitly considers climate actions, biodiversity protection and restoration as land uses and the land use strategy needs to align with climate and biodiversity obligations. The national land use strategy must be underpinned by regularly updated spatial data sources and include a spatial planning framework.
- Changes in land use practices are needed in the forestry, agriculture and energy sectors to achieve climate and biodiversity benefits through nature-friendly forestry and farming practices and appropriate siting of renewable energy infrastructures. Additionally, systemic change is needed for individuals, businesses, industry, and society as a whole, to reduce energy and resource consumption, and to minimise waste.
- Definitions of “climate neutrality” and “biodiversity-rich” are needed for the development of appropriate land use strategies and to better account for biodiversity and biodiversity change.
- Increased knowledge generation and sharing are needed to resolve key uncertainties, assess the impacts of actions and policies, and continually update climate and biodiversity actions in response to data.
- International impacts of climate and biodiversity action need to be assessed to avoid “off-shoring” climate and biodiversity impact. Ireland should not contribute to biodiversity and carbon decline here or elsewhere through resource exports or imports.

*Table 6-1 Summary of key recommendations from this study. Enablers and challenges are highlighted that can support these and prioritise recommendations to be addressed. Priorities are also assigned to these recommendations (scale of 1-6), with 1 indicating the highest priority.*

| ***Broad topic*** | **Impacted Sector** | **Description** | **Enabler/Challenge** | **Priority** |
|---|---|---|---|---|
| *Implement statutory obligations* | All | Statutory obligations such as national and EU Biodiversity Strategies and the Nature Restoration law require specified areas to be protected or restored. | The areas to be protected or restored need to be selected. A spatial prioritisation approach will help achieve these targets. | 1 |
| | | Produce a national Nature Restoration Plan in a spatial framework as obligated under Nature Restoration Law. | Implement restoration (20% of degraded ecosystems) and protection (30% land and sea areas) by 2030. Climate and biodiversity benefits will be spatially context dependent. | |
| *Policy alignment* | All | Strategy needed to align carbon budget process with biodiversity, sustainable food production, water quality. | Policy on carbon mostly operates in isolation, but land use specifically has multiple functions and benefits. | 1 |
| | | | Agreement on land use strategic approach will inform the implementation, and alignment of policies. | |

| ***Broad topic*** | **Impacted Sector** | **Description** | **Enabler/Challenge** | **Priority** |
|---|---|---|---|---|
| *Land use strategy* | All | Agreement needed on strategy for land use to address climate change and biodiversity challenges in an integrated way | Different sectors need to agree considering socioeconomic factors. This will allow for developing a multifunctional landscape. | 2 |
| | | | A land use strategy, informed by spatial data sources will allow for the development of a spatial land use plan that can be implemented to advise stakeholders on alternative uses, and to develop schemes to incentivise change. | |
| *Spatial data sources* | All | Up to date, spatial information needed related to land cover, land use, and infrastructure. | Regular updates and refinements of maps for land uses, land cover (National Land Cover 2018) and infrastructure are needed. These spatial datasets will enable modelling of and planning for climate mitigation, biodiversity protection and restoration for a multi-functional landscape (mosaic, buffer zones, protected areas). | 2 |
| | | | Include conservation actions such as biodiversity protection and restoration as specified land uses in National Land Use Review and National Land Use Map. | |
| *Spatial planning framework* | All | Need a national land use strategy that can be implemented spatially which includes climate and biodiversity actions as land uses. | A spatially informed framework using an approach like that used in Finland could help Ireland prioritize areas with exclusive services (biodiversity hotspots) where biodiversity is prioritized over other services and areas with co-benefits. This will allow for the development of a multifunctional landscape. | 2 |
| | | | The impact of climate and biodiversity actions vary in space. | |
| | | | It is  necessary to plan for the effects of fragmentation and connectivity. | |
| | | | One land parcel may be used for more than one purpose (e.g. solar panels in grazing areas). | |
| | | | Biodiversity only occurring in one place needs protection. | |
| | | Need to optimise land use. | Most suited land use, for a specific area. | |
| | | Need to plan for future risks. | Fire, pests, and diseases spread over the landscape. | |
| | | Agree on the scale at which impacts are assessed. | Impacts vary across different scales (site, catchment, regional or national). | |
| *Change in land use practices* | Forestry | Nature-friendly or close-to-nature management of forestry (e.g. Closed Canopy Forestry or continuous cover forestry) where possible. | Increased afforestation which considers species diversification (including native conifer and broadleaved species) across the landscape; diversity of management practices (including lower impact), plans for sustained carbon stock and wood production and hence a healthy age profile of the national forest estate and a spatial distribution thereof, buffer zones to protect against fire, pests, diseases may all benefit climate mitigation. | 3 |
| | Agriculture | Lower impact and nature-friendly agricultural practices. | Encourage adoption of lower impact, more efficient practices related to livestock, and nutrient/fertilizer application, conservation agriculture. | |

| *Broad topic* | Impacted Sector | Description | Enabler/Challenge | Priority |
|---|---|---|---|---|
| | Energy | Existing infrastructure and disturbed areas. | Prioritise solar infrastructure on existing built infrastructure | |
| | | . | Avoid solar farms in areas of high biodiversity value. | |
| | Energy | Efficiency of energy systems. | Assess energy intensity together with biodiversity risk and mitigations to maximise energy per unit area and assess any trade-offs. | |
| | Energy | Demand for energy, and resources. | Potential negative impacts on biodiversity can be mitigated by encouraging lower demand. | |
| *Definitions* | All | Agree on a national definition of climate/carbon dioxide/ greenhouse gas neutrality. | How different greenhouse gas emissions are dealt with could have a large impact on land use recommendations and consequences for biodiversity | 4 |
| | | Define "biodiversity-rich" for protected areas and wider countryside/seascapes. | Agreement on what “biodiversity rich” means will allow us to more accurately account for biodiversity in the landscape and determine risks and opportunities. | |
| *Knowledge generation, sharing* | Forestry | Understanding of impacts of climate change mitigation measures and biodiversity measures on full suite of ecosystem services (and each other) needs to be increased. | Continued long-term investment in research will allow for more accurate modelling of carbon budgets and assessing the impact of these measures on biodiversity. | 5 |
| | Agriculture Forestry | There is currently a knowledge gap specific to Ireland of the impact of mitigation measures on the carbon budgets and biodiversity. | Field-based research and assessments, e.g. in forestry need to be expanded. | 5 |
| | All | Agreements reached to share knowledge related to climate and biodiversity as well as data sources freely available | Shared knowledge will help Ireland reach the biodiversity and carbon budget targets more easily. Models can be improved, and shortcomings identified. | |
| *International considerations* | All | Avoid shifting biodiversity impacts offshore - assess and mitigate the risks of biodiversity "leakage" for climate actions. Avoid importing or using resources that negatively impact the local carbon budget and biodiversity. | Climate change and biodiversity loss are international challenges. Any impact on biodiversity in Ireland (positive or negative) will impact international biodiversity targets. | 6 |
| *Temporal dimensions* | All | Strategy for assessing temporal impacts of interventions | Emission losses following land use change are currently ignored. | |

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