epaResearch

**Evidence Synthesis Report:** 4

# Land Use Review: Fluxes, Scenarios and Capacity Synthesis Report

**Authors:** Eamon Haughey, David Styles, Matthew Saunders, Ruth Bennett Coady and James Moran

**www.epa.ie**

Rialtas na hÉireann
Government of Ireland

# Environmental Protection Agency

The EPA is responsible for protecting and improving the environment as a valuable asset for the people of Ireland. We are committed to protecting people and the environment from the harmful effects of radiation and pollution.

## The work of the EPA can be divided into three main areas:

**Regulation:** Implementing regulation and environmental compliance systems to deliver good environmental outcomes and target those who don't comply.

**Knowledge:** Providing high quality, targeted and timely environmental data, information and assessment to inform decision making.

**Advocacy:** Working with others to advocate for a clean, productive and well protected environment and for sustainable environmental practices.

## Our Responsibilities Include:

### Licensing

> Large-scale industrial, waste and petrol storage activities;
> Urban waste water discharges;
> The contained use and controlled release of Genetically Modified Organisms;
> Sources of ionising radiation;
> Greenhouse gas emissions from industry and aviation through the EU Emissions Trading Scheme.

### National Environmental Enforcement

> Audit and inspection of EPA licensed facilities;
> Drive the implementation of best practice in regulated activities and facilities;
> Oversee local authority responsibilities for environmental protection;
> Regulate the quality of public drinking water and enforce urban waste water discharge authorisations;
> Assess and report on public and private drinking water quality;
> Coordinate a network of public service organisations to support action against environmental crime;
> Prosecute those who flout environmental law and damage the environment.

### Waste Management and Chemicals in the Environment

> Implement and enforce waste regulations including national enforcement issues;
> Prepare and publish national waste statistics and the National Hazardous Waste Management Plan;
> Develop and implement the National Waste Prevention Programme;
> Implement and report on legislation on the control of chemicals in the environment.

### Water Management

> Engage with national and regional governance and operational structures to implement the Water Framework Directive;
> Monitor, assess and report on the quality of rivers, lakes, transitional and coastal waters, bathing waters and groundwaters, and measurement of water levels and river flows.

### Climate Science & Climate Change

> Publish Ireland's greenhouse gas emission inventories and projections;
> Provide the Secretariat to the Climate Change Advisory Council and support to the National Dialogue on Climate Action;
> Support National, EU and UN Climate Science and Policy development activities.

### Environmental Monitoring & Assessment

> Design and implement national environmental monitoring systems: technology, data management, analysis and forecasting;
> Produce the State of Ireland's Environment and Indicator Reports;
> Monitor air quality and implement the EU Clean Air for Europe Directive, the Convention on Long Range Transboundary Air Pollution, and the National Emissions Ceiling Directive;
> Oversee the implementation of the Environmental Noise Directive;
> Assess the impact of proposed plans and programmes on the Irish environment.

### Environmental Research and Development

> Coordinate and fund national environmental research activity to identify pressures, inform policy and provide solutions;
> Collaborate with national and EU environmental research activity.

### Radiological Protection

> Monitoring radiation levels and assess public exposure to ionising radiation and electromagnetic fields;
> Assist in developing national plans for emergencies arising from nuclear accidents;
> Monitor developments abroad relating to nuclear installations and radiological safety;
> Provide, or oversee the provision of, specialist radiation protection services.

### Guidance, Awareness Raising, and Accessible Information

> Provide independent evidence-based reporting, advice and guidance to Government, industry and the public on environmental and radiological protection topics;
> Promote the link between health and wellbeing, the economy and a clean environment;
> Promote environmental awareness including supporting behaviours for resource efficiency and climate transition;
> Promote radon testing in homes and workplaces and encourage remediation where necessary.

### Partnership and Networking

> Work with international and national agencies, regional and local authorities, non-governmental organisations, representative bodies and government departments to deliver environmental and radiological protection, research coordination and science-based decision making.

## Management and Structure of the EPA

The EPA is managed by a full time Board, consisting of a Director General and five Directors. The work is carried out across five Offices:

1. Office of Environmental Sustainability
2. Office of Environmental Enforcement
3. Office of Evidence and Assessment
4. Office of Radiation Protection and Environmental Monitoring
5. Office of Communications and Corporate Services

The EPA is assisted by advisory committees who meet regularly to discuss issues of concern and provide advice to the Board.

# Land Use Review: Fluxes, Scenarios and Capacity Synthesis Report

## Evidence Synthesis Report


Prepared for the Environmental Protection Agency

by

Department of Natural Resources and the Environment, School of Science and Computing,
Atlantic Technological University, ATU Galway

**Authors:**

**Eamon Haughey, David Styles, Matthew Saunders, Ruth Bennett Coady and James Moran**



**ENVIRONMENTAL PROTECTION AGENCY**
An Ghníomhaireacht um Chaomhnú Comhshaoil
PO Box 3000, Johnstown Castle, Co. Wexford, Ireland

Telephone: +353 53 916 0600  Fax: +353 53 916 0699
Email: info@epa.ie  Website: www.epa.ie

## ACKNOWLEDGEMENTS

This report was funded by the Department of the Environment, Climate and Communications and the Department of Agriculture, Food and the Marine.

The authors would like to acknowledge the funders.

The authors thank Hannah Daly (University College Cork) for feedback regarding the report structure and Fiona O'Rourke (EPA) and Jonathan Derham (EPA) for their support in coordination of the project. Thanks go also to the members of the Land Use Review Steering Committee, Marc Kierans (Department of the Environment, Climate and Communications (DECC)), Eimear Cotter (EPA), Francis Morrin (Department of Agriculture, Food and the Marine (DAFM)), Stuart Meikle, Sean Bell (DAFM), Noel Regan (DECC), Gerry Clabby (DECC), Paul Hogan (Department of Housing, Local Government and Heritage (DHLGH)) and Alan Matthews (Trinity College Dublin), for their feedback and input.

## DISCLAIMER



This report is based on research carried out from February to July 2022. More recent data may have become available since the research was completed.

Published by the Environmental Protection Agency, Ireland

ISBN: 978-1-80009-095-8 March 2023

Price: Free Online version

# Project Partners

**Dr Eamon Haughey**
Department of Natural Resources and the Environment
School of Science and Computing
Atlantic Technological University
ATU Galway City
Galway
Ireland
Tel.: +353 (0) 91 742154
Email: eamon.haughey@atu.ie

**Dr David Styles**
Ryan Institute
School of Biological and Chemical Sciences
University of Galway
Galway
Ireland
Email: david.styles@nuigalway.ie

**Dr Matthew Saunders**
Botany Department
School of Natural Sciences
Trinity College Dublin
Dublin 2
Ireland
Email: saundem@tcd.ie

**Ruth Bennett Coady**
Department of Natural Resources and the Environment
School of Science and Computing
Atlantic Technological University
ATU Galway City
Galway
Ireland
Email: ruthbcoady@gmail.com

**Dr James Moran**
Department of Natural Resources and the Environment
School of Science and Computing
Atlantic Technological University
ATU Galway City
Galway
Ireland
Email: james.moran@atu.ie

# Contents

# List of Figures

# List of Tables

# Executive Summary

In 2020, grasslands were the dominant form of land use in Ireland, accounting for 59.2% of total land use. There were also significant areas of wetlands (17.2%), forest land (11.0%) and croplands (10.4%). Between 1990 and 2020, there was a 51.4% increase in forest land, a 19.9% increase in settlement land and an 8.5% decrease in wetlands, whereas the picture was relatively stable for croplands and grasslands. However, much of the major land use change in Ireland happened prior to 1990, with for example forestry increasing from around 1.4% in 1918 to the present level of around 11%. Meanwhile, wetland and cropland areas have decreased substantially since the middle of the 19th century. A regional analysis of land cover in Ireland has shown strong differences in the distribution of many land cover categories. For example, croplands and infrastructure land (e.g. urban areas and other artificial surfaces) are more dominant in the east and south-east of the country, while the land cover categories most associated with high biodiversity value occur predominantly in the border, west and mid-west regions.

The agriculture, forestry and other land use (AFOLU) sector was a significant source of net greenhouse gas (GHG) emissions in Ireland over the 2016–2020 period, accounting for an average of 27,707 (±888) kt of carbon dioxide equivalents per year (kt $CO_2$ eq $yr^{-1}$). The single largest contributor to GHG emissions from agricultural activity was methane ($CH_4$) from ruminant livestock, followed by nitrous oxide ($N_2O$) emissions from nitrogen (both organic and inorganic) application to soils, and the deposition of excreta. At the same time, forest land and associated harvested wood products provided an important net sink, which averaged –2957 (±338) kt $CO_2$ eq $yr^{-1}$ from 2016 to 2020, despite losses of carbon from afforested organic soils. In 2020, although grassland (land use category) on mineral soils provided an estimated net sink of –2291 kt $CO_2$ eq overall, this was outweighed by emissions of 8432 kt $CO_2$ eq in 2020 from grasslands on organic soils, even though organic soils accounted for only 8.1% of the total grassland area. It is noted that, in line with international conventions, the national GHG inventory currently reports GHG emissions for agriculture and for land use, land use change and forestry (LULUCF) separately and not combined as AFOLU.

Already observed changes to the global climate system include increases in mean temperatures, atmospheric $CO_2$ concentration, the frequency and intensity of warm or hot extremes, heavy precipitation events, agricultural and ecological droughts, co-occurring droughts and heatwaves, and extreme sea levels; and decreases in cold extremes. Over the period 2081–2100, projected temperature increases for northern Europe range from 2.6°C to 5.4°C under low to high global warming scenarios. At the national level (under a moderate global warming scenario), projections for mid-century indicate increases in annual temperatures of 1.0–1.2°C, a decrease in summer precipitation and an increase in the occurrence of heatwaves, especially in the south and east of the country, as well as an increase in the frequency of heavy precipitation events. A decrease in the number of frost days, with an associated increase in the length of the growing season, is also projected. It is expected that $CO_2$ fertilisation and an extended growing season will result in increased gross primary production; however, this may be counteracted by an increase in the frequency and severity of extreme events also projected by mid-century. The projected increases in heavy precipitation events by mid-century are likely to have an impact on the trafficability of managed soils, while droughts and heatwaves may lead to carbon losses from peatlands and a higher frequency of wildfires.

To explore the level of change required in agriculture and land use that would be commensurate with a net-zero AFOLU sector by 2050, a set of indicative scenarios were developed. The scenarios were based on the GOBLIN model approach along with a set of simplified baseline assumptions. These scenarios suggest that achieving net-zero GHG emissions in the AFOLU sector by 2050 will be very challenging. Only those scenarios that include all of the following measures are expected to be able to achieve net zero by 2050: effective abatement of livestock emissions (an emissions decoupling of approximately 30%) plus ruminant livestock number reduction (up to 30%

considered); ambitious organic soil rewetting (up to 90% of drained organic soils considered); and large areas of afforestation (up to 875,000 ha of new forest by 2050 considered). This was the case whether AFOLU $CH_4$ emissions were included in or excluded from the overall GHG balance; however, when $CH_4$ was excluded and dealt with using a separate target, it was possible to reach net zero with a smaller area of additional forest by 2050 (500,000 ha).

The effective targeting and implementation of climate mitigation measures in the AFOLU sector together with subsequent land management will largely determine whether land use change results in benefits to or substantial trade-offs for biodiversity and water resources. The level of change to the AFOLU sector required to meet net-zero targets under the indicative scenarios developed here would have major consequences for water quality and biodiversity, as well as for many other provisioning and non-provisioning ecosystem services. Continued biodiversity loss has the potential to hamper the effectiveness of mitigation in the AFOLU sector and also to reduce the resilience of ecosystems to climate change extremes. The impacts of large-scale rapid afforestation on water quality, water quantity and biodiversity will vary throughout the forestry management cycle and according to other factors such as the species composition of the area afforested, tree species mix and forestry management decisions. The restoration of degraded peatlands as a climate mitigation measure can have significant co-benefits for biodiversity, water quality and water regulation. However, successful restoration depends on a range of site-specific conditions, including the degree of prior modification of peatlands through drainage, peat extraction and conversion to grassland, cropland or forestry land uses. Measures taken to reduce agricultural emissions including related changes in livestock densities are likely to have complex interactions with biodiversity and water quality.

An integrated land use management approach is required to target land use to meet multiple goals cognisant of the trade-offs and synergies between them while balancing environmental, social and economic outcomes. Strategic targeting of land use should acknowledge the varying capacity of different land types to provide a diverse range of ecosystem services, from provisioning (e.g. food and fibre), regulating (e.g. climate, water) and supporting (e.g. nutrient cycling) services to cultural (aesthetic, recreational) services. Such an approach can support policymakers, land managers and land users to develop and implement land use strategies that meet the needs of society while protecting natural resources.

The land use and climate change policy landscape of the European Union and the Government of Ireland, as well as of state- or semi-state agencies in Ireland, is complex and occurs across multiple time horizons. An analysis of key policy documents has indicated that in many cases the stated policy targets were not consistent with the levels of land use change required to meet net-zero targets in the AFOLU sector by 2050, based on the indicative scenarios developed in this report. This was especially apparent for afforestation, for which policy targets were much lower than those used in modelled scenarios. While there is significant scope for climate actions to be deployed across the land system in Ireland, adequate enabling conditions are also required. Important knowledge gaps that hamper rapid progress across multiple sectors include the need for more detailed data on land cover/land use and soil carbon fluxes, uncertainty about climate impacts on the land system and the contribution of areas of semi-natural vegetation to climate mitigation. There is also a need for more effective knowledge sharing and innovation development with land managers, to enable effective and timely climate actions.

# 1 Introduction: Land Use, Land Cover and Greenhouse Gas Fluxes

## 1.1 Scope and Overview of the Work

This synthesis report summarises the research carried out as part of the Land Use Review: Fluxes, Scenarios and Capacity and its key findings, conclusions and policy recommendations, as set out in detail in the accompanying main report (which is available for download from the EPA website). The specific scope of the work and general structure of the main report was agreed by the author team and the Land Use Review Steering Committee at the outset of the project. This process both identified key focus areas and provided boundaries to the review. Since this project was from the outset focused on the scientific literature, socioeconomic factors were not included in the agreed scope. The author team note, however, that socioeconomic factors are a critical consideration in land use, and further follow-up work in that sphere is recommended for future evidence reviews.

## 1.2 Main Report Structure

- Chapter 1. Current Land Cover, Land Use and Trends
- Chapter 2. Greenhouse Gas Fluxes from Agriculture, Forestry and Other Land
- Chapter 3. Climate Change Scenarios and Impacts
- Chapter 4. Land Use Scenarios for Net Zero
- Chapter 5. Land Use Change Impacts: Synergies and Trade-offs
- Chapter 6. Options to Support Policy Development

Chapter 1 provides an analysis of current land use and cover in Ireland, and Chapter 2 explores related greenhouse gas (GHG) fluxes from the agriculture, forestry and other land use (AFOLU) sector. This is followed in Chapter 3 by a summary of the observed and projected changes to the regional and national climate system under various global warming scenarios. Chapter 3 also provides a high-level analysis of expected climate change impacts on the functioning of the land system in Ireland. A set of stylised indicative land use change scenarios are outlined in Chapter 4, based on the target of achieving territorial net-zero GHG emissions in the AFOLU sector by 2050. Chapter 5 analyses the potential impacts of these land use change scenarios on key ecosystem services, such as water quality, carbon storage and biodiversity conservation. This assessment also examines the trade-offs and synergies between the levels of land use change envisaged in the stylised scenarios based on key environmental indicators. Finally, in Chapter 6 options to support policy development are explored in the context of the existing policy landscape and key knowledge gaps are identified.

To explore cross-cutting or overarching issues, the following information boxes have been used in the main report:

- Information Box 2.1: Methane emissions and metrics;
- Information Box 3.1: Representative concentration pathways (RCPs) and shared socioeconomic pathways (SSPs);
- Information Box 4.1: Net-zero ambition for the AFOLU sector.

# 2 Overview of the Research

## 2.1 Land Use and Land Cover

The latest available land use data at the national level were extracted from the national GHG inventory for 2020 (these were the most recently available data at the time of writing) (EPA, 2022a). Trends in land use from 1990 to 2019 were investigated using Central Statistics Office (CSO) land use data (CSO, 2021). We note that much of the significant land use change that has occurred in Ireland happened prior to 1990 and so before the advent of current data recording methods. To place current land use trends in context, some key trends in historical data were explored.

Using CORINE land cover data, a category mapping exercise was conducted to create categorisations of land cover that provided a more useful proxy measure for land use and so enabled a more direct analysis of land interactions with GHG fluxes (categorisation adapted from Arneth *et al*., 2019). This resulted in seven main land cover classes, and based on this categorisation a land cover map was produced (Figure 2.1) (for a detailed breakdown, see Table A1.1 in the main report). To investigate regional differences in how land is used in Ireland, the adapted land cover categorisation was used as a proxy (as detailed spatial land use data were not available at time of writing; we note that work to address this is ongoing). Nomenclature of Territorial Units for Statistics (NUTS) mapping at the third level (NUTS3) was overlaid on the generated land cover map, and spatial data were then extracted. The analysis was conducted using GQIS geographic information systems software (QGIS, 2022).

## 2.2 Analysis of Greenhouse Gas Fluxes from Agriculture, Forestry and Other Land

The latest available GHG data from the national GHG inventory of Ireland were used where possible; these were from the 1990–2020 inventory (EPA, 2022a). GHG fluxes were assessed in carbon dioxide equivalents ($CO_2$eq) based on standard inventory reporting practices that use the global warming potential metric $GWP_{100}$. To account for and explore interannual variation in emissions, where possible, 5-year (2016–2020) average values and their variances were quoted. Providing an AFOLU summary necessitated combining the agriculture and the land use, land use change and forestry (LULUCF) categories that the EPA is required to use for reporting GHG emissions under the United Nations Framework Convention on Climate Change. For transparency, a disaggregated analysis was shown along with an indication of whether a particular component belonged to either the agriculture or the LULUCF category.

## 2.3 Observed and Projected Climate Change and Impacts

An analysis of observed and projected climate change was conducted at three levels: global, regional and national. The global analysis was very high level and was used to provide context, drawing on the latest Intergovernmental Panel on Climate Change (IPCC) assessment contribution from Working Group I as part of the IPCC's sixth assessment cycle (IPCC, 2021). At the regional level, the northern Europe region (of which Ireland is part) was selected, with information drawn again from the latest IPCC assessment report (IPCC, 2021). Finally, an analysis of observed climate change at the national level drew on the analysis in the EPA's *Climate Status Report for Ireland 2020* (EPA, 2021), while projections for Ireland were drawn from the analysis by Nolan and Flanagan (2020). We note that one limitation encountered during this analysis was poor compatibility between the baselines and time horizons used for climate change projections between the global, regional and national climate change assessments. This limitation makes it more challenging to relate regional to global climate projections for Ireland.

A systematic literature search approach was taken to assess the latest information related to climate change impacts on the land system in Ireland. Boolean search terms were used to find relevant research from ISI Web of Science, the Food and Agriculture

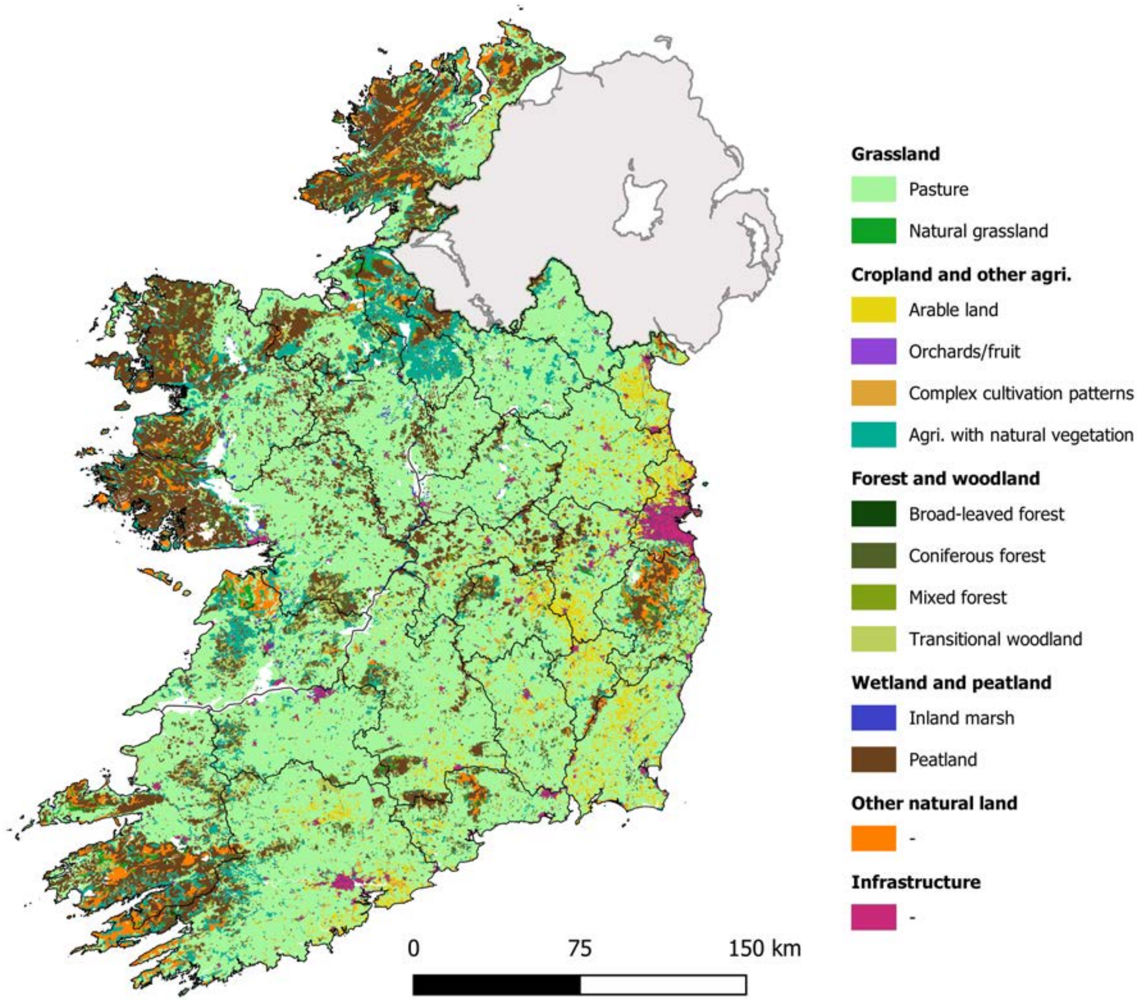


**Figure 2.1. Main and associated sub-classes of land cover in Ireland as grouped in this report. Complied using CORINE (2018) data. A summary of the area extent of each category is given in Table A1.1 of the main report.**

Organization of the United Nations publications library, the online library of the Organisation for Economic Co-operation and Development (OECD iLibrary) and the IPCC search engine. The literature search was limited to English-language studies, with no limitation on publication date. Each potential study was initially assessed by title to decide on its suitability, then by abstract to determine its relevance to our research and lastly by main text to extract the most relevant information. (For full details of the search methodology, see Appendix 2 of the main report.)

## 2.4 Land Use Change Scenarios for Net Zero

A set of indicative land use change scenarios were developed, and their capacity to facilitate net-zero GHG emissions from the AFOLU sector in Ireland by 2050 was assessed. Scenarios were informed by the imperative to reach net zero and subject to only biophysical constraints, i.e. they are not projections based on socioeconomic modelling, but rather they take a foresight approach commensurate with the necessarily ambitious objective.

Scenario permutations in the AFOLU sector to 2050 were derived based on seven core scenarios developed in consultation with project stakeholders using 2018 national inventory emissions and land area data as a baseline. The results were presented as changes in the land areas in 2050, and resulting GHG fluxes, in relation to achieving the target for climate neutrality by the year 2050.

## 2.5 Some Important Baseline Assumptions

The following baseline assumptions were made:

- grassland area approximately 4200 kha;
- forestry area approximately 770 kha;
- approximately 335 kha of organic soils under grass are drained;
- approximately 70 kha of exploited (drained) raised bog;
- approximately 1.37 million dairy cows and 0.98 million suckler cows.

The land use change (including changes to livestock density) associated with each of the scenarios is outlined in Table 2.1. The core scenarios are as follows (see the main report for further details of the permutations shown in Table 2.1):

- BAU: a very simple "business-as-usual" trajectory based on the average afforestation rate over the past 10 years;
- S1: increased afforestation;
- S2: rewetting of peatlands and used organic soils;
- S3: agriculture optimisation (defined here based on two components, namely increased production efficiency and change in livestock numbers);
- S4: combination of part or all of S1, S2 and S3 (four permutations are outlined);
- S5: space for nature (in addition to S4);
- S6: space for bioenergy (grassland or perennial crop based; in addition to S4);
- S7: space for additional croplands.

GHG balances are calculated based on $GWP_{100}$ and $CO_2$eq values from the IPCC's fifth assessment report (i.e. 28 for methane ($CH_4$) and 265 for nitrous oxide ($N_2O$)). Balances are presented with and without $CH_4$, accounting for a possible future policy shift towards separate measurement of $CH_4$.

## 2.6 Analysis of Land Use Change Impacts

The potential impacts of the land use changes outlined under the different indicative scenarios on the land system in Ireland were explored. This analysis concentrated mainly on the impacts of the major land use changes that were found to be commensurate with meeting the target of net-zero AFOLU emissions by 2050. These are large-scale afforestation, agriculture optimisation (increased livestock production efficiency, increases/decreases in livestock density), peatland restoration (restoration/rehabilitation of exploited peatlands, rewetting of grasslands on organic soils) and additional land use options (space for nature, bioenergy from grasslands and additional croplands) (Table 2.1). An assessment was undertaken of the synergies and trade-offs associated with the land use change measures (see Table 3.3) included under the set of scenarios in this report. We note that this high-level assessment is qualitative in nature and based on the expert opinions of the authors. However, it provides an accessible first point of information with regard to the key interactions we identify.

## 2.7 Analysis of Policy Interactions in the Land Use Space

An analysis of current policy at the EU and national levels was conducted with a view to (1) summarising the latest stated objectives and (2) assessing the compatibility of these policies with the level of land use change identified as compatible with net-zero AFLOU emissions under the illustrative scenarios in this report. This policy area is complex because of the number of actors (e.g. EU institutions, national government departments, semi-state bodies) and the range of separate but interlinked policy documents produced by them. A further complicating factor is the various time horizons used across the policy documents. The list of policy documents assessed was by no means exhaustive but includes the most relevant and recently published documents available. We note that policy documents "in preparation" at the time of writing were not included in the analysis (but in some cases the forthcoming updated editions were mentioned for clarity), and this report includes only those documents that are published and publicly available.

**Table 2.1. Overview of major land use changes associated with each modelled scenario by 2050 (including $CH_4$)**

| | Afforestation | Agriculture optimisation | | | Peatland restoration | | Additional land use options | | |
|---|---|---|---|---|---|---|---|---|---|
| Scenario | Total ha (annual rate ha yr$^{-1}$) | Increase in livestock production efficiency (%) | Change in total ruminants (%) | Change livestock density (%) | Rewetting grasslands on organic soils (ha) | Exploited peatland restoration (ha) | Space for nature | Bioenergy from grasslands | Additional croplands |
| S1a | 200,000 (8000) | 0 | 0 | 5 | | | | | |
| S1b | 875,000 (35,000) | 0 | 0 | 26 | | | | | |
| S2 | 125,000 (5000) | 0 | 0 | 13 | 302,000 | 70,000 | | | |
| S3a | 125,000 (5000) | 30 | 0 | 3 | | | | | |
| S3b | 125,000 (5000) | 30 | –30 | –28 | | | | | |
| S4a | 200,000 (8000) | 30 | 0 | 16 | 302,000 | 70,000 | | | |
| S4b | 875,000 (35,000) | 30 | 0 | 42 | 302,000 | 70,000 | | | |
| S4c | 200,000 (8000) | 30 | –30 | –19 | 302,000 | 70,000 | | | |
| S4d | 875,000 (35,000) | 30 | –30 | 0 | 302,000 | 70,000 | | | |
| S5 | 875,000 (35,000) | 30 | –30 | 16 | 302,000 | 70,000 | 420,000 | | |
| S6 | 875,000 (35,000) | 30 | –30 | 16 | 302,000 | 70,000 | | 420,000 | |
| S7 | 875,000 (35,000) | 30 | –30 | 16 | 302,000 | 70,000 | | | 420,000 |

# 3 Examination of the Findings

## 3.1 Land Use and Land Cover: Key Findings

The land use in Ireland in 2020 is outlined by category in Figure 3.1. In that year, grassland constituted the largest land use category, at 59.2%; followed by significant areas of wetland (17.2%), which include peatlands and other wetland systems; forest (11%); croplands (10.4%); settlements (1.8%); and other land (0.4%). Beef cattle, dairy and sheep farming are the primary uses of grasslands in Ireland, and the associated outputs make up the largest share of the total economic value of the agri-food sector. The second largest land use category, wetlands, is predominantly made up of peatlands, which are sub-classified into three main categories: blanket bogs, raised bogs and fens (Renou-Wilson, 2018). Forestry plantations in Ireland are dominated by conifers, with only 27.0% of the country's currently stocked forest area under broadleaved species (DAFM, 2022). The area of forestry has increased dramatically over the last century in Ireland, from a low of 1.4% in 1918 to its current level, but it remains small compared with the EU average. Ireland's cropland area is used predominantly for the cultivation of the three main cereal crops: barley, wheat and oats (DAFM, 2021a). At farm level, specialist tillage and mixed crop and livestock farms accounted for 3.4% and 1.3%, respectively, of all farms in 2020 (CSO, 2020).

A regional analysis of land cover showed that grasslands are relatively evenly distributed across the country, with a total of 52.5% in the mid-west, south-west and west regions (Table 3.1). However, wetland cover is not distributed evenly, with the border, west and south-west regions accounting for 82.9% of the total between them (Table 3.1); by contrast, only 1.4% is in the south-east. Although the midlands and mid-west account for only 6.7% and 5.5% of wetland cover, respectively, the wetlands in these regions are likely to account for the majority of raised bog (Renou-Wilson, 2018). The largest share of forest and woodland cover is in the border, west, mid-west and south-west regions, at 72.1%, with substantially less cover in the south-east (Table 3.1).

The distribution of the "other agricultural land" category, which includes complex cultivation patterns and agriculture with areas of natural vegetation, was dominated by three regions: border at 32.6%, west at 21.3% and south-west at 17.7%. The relatively high level of complex agricultural land in these regions has significant overlap with semi-natural areas and is highly relevant to biodiversity and space for nature. There are strong regional differences in cropland

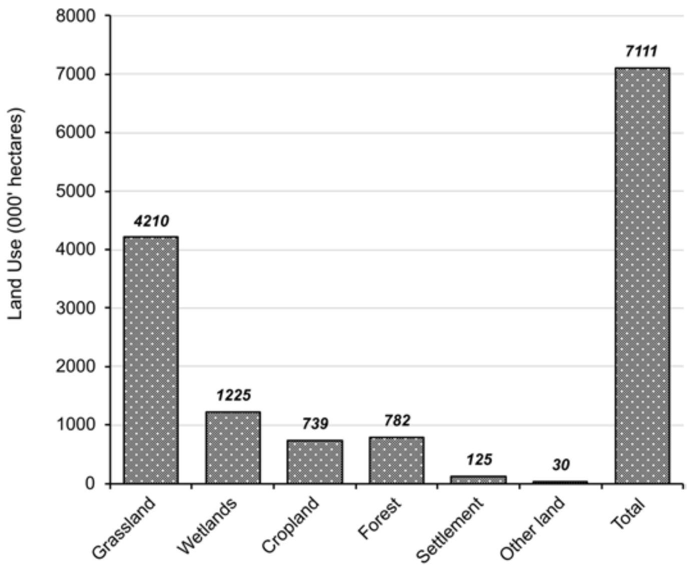


**Figure 3.1. Land use in Ireland in 2020. Data source: EPA (2022a).**

**Table 3.1. Regional breakdown of land cover categories as a proportion (%) of the total area of each land cover category (using the NUTS3 classifications)**

| Category | Regional distribution of land cover categories (%) | | | | | | | Category total area ('000 ha) |
|---|---|---|---|---|---|---|---|---|
| | Border | Mid-east and Dublin | Midlands | Mid-west | South-east | South-west | West | |
| Infrastructure | 9.1 | 40.9 | 6.7 | 10.8 | 9.7 | 14.1 | 8.7 | 168.7 |
| Croplands | 1.3 | 40.5 | 8 | 6.3 | 30.1 | 13.4 | 0.4 | 320.2 |
| Other agricultural land | 32.6 | 6 | 5.6 | 12 | 4.8 | 17.7 | 21.3 | 544.8 |
| Grasslands | 12.8 | 10.8 | 11.5 | 18 | 12.4 | 17.3 | 17.2 | 3942.1 |
| Forest and woodland | 17.1 | 9 | 9.9 | 17.9 | 9 | 18.6 | 18.5 | 672.2 |
| Other natural land | 23.8 | 11.3 | 0.3 | 9.2 | 4.6 | 32.1 | 18.7 | 217.4 |
| Wetlands (including peatlands) | 25.7 | 3.5 | 6.7 | 5.5 | 1.4 | 17.4 | 39.8 | 992.7 |

**Other agricultural land includes complex cultivation patterns, agriculture with areas of natural vegetation, orchards and fruit production. Other natural land includes moors and heaths, beaches, rock, sparsely vegetated areas and burnt areas. Infrastructure includes urban fabric, industrial areas, transport and recreational areas. See Table A1.1 in the main report for area breakdown by category.**

cover, with 40.5% recorded in the mid-east and Dublin region and a further 30.1% in the south-east (Table 3.1). By contrast, only 1.3% and 0.4% of cropland cover is recorded in the border and west regions, respectively. Infrastructure, which includes urban areas, transport and industrial areas, also shows strong regional differences, with over 40% occurring in the mid-east and Dublin regions (Table 3.1).

## 3.2 Terrestrial Greenhouse Gas Fluxes: Key Findings

Over the 2016–2020 period, the average annual emissions from the agriculture sector were estimated at 20,620 (±525) kt $CO_2$ eq $yr^{-1}$ (Figure 3.2). Agriculture is responsible for the largest share of national GHG emissions in Ireland, accounting for 37.1% of the total in 2020[1] (EPA, 2022b). The large contribution of agricultural activity to national emissions has been relatively consistent since the reporting of GHGs began in 1990, when agriculture had a 35.5% share. Ireland is an outlier among EU Member States in terms of the dominance of its agricultural emissions (Haughey, 2021). In 2020, agriculture accounted for 11.8% of net GHG emissions across the 27 EU Member States (EU-27), including the LULUCF sector (EEA, 2021). This is attributable to a combination of the large ruminant livestock numbers in Ireland, which corresponds to grasslands being the main land use category, and a relatively low level of heavy industry.

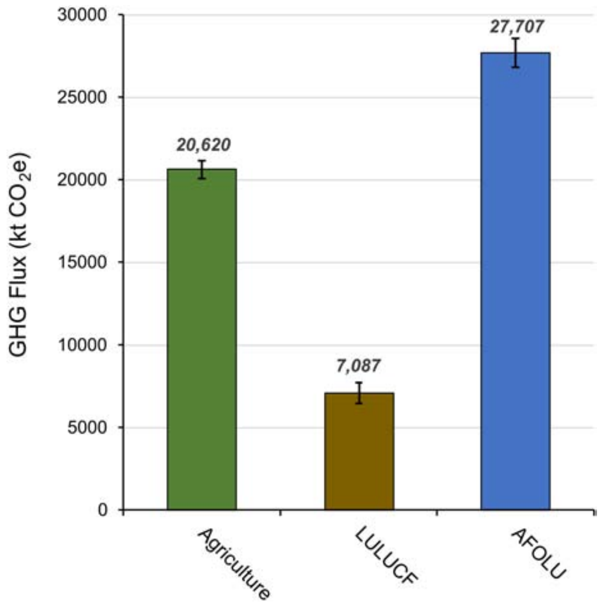


**Figure 3.2. Annual average (2016–2020) GHG flux for agriculture, LULUCF (sum of sinks and sources) and AFOLU (combined balance of the agriculture and LULUCF categories) in Ireland (±1 SD).**

The LULUCF category is unique in that it can be both a source and a sink of emissions due to carbon sequestration in soils and biomass. Therefore, the LULUCF sector is generally described in terms of sinks, sources and the net balance of GHG fluxes taking place. Between 2016 and 2020, the annual average balance of LULUCF GHG sources and sinks

1 Note that this total excludes the LULUCF sector.

resulted in this sector being a net source of 7087 (±658) kt $CO_2$ eq $yr^{-1}$ (Figure 3.2). It is noteworthy that, relative to the total, the variance across years was considerably higher for LULUCF than for the agriculture sector. This overall balance includes an important net sink in the forestry and harvested wood products categories; however, this was outweighed by the combined GHG emissions from grasslands and wetlands. Combined, the agriculture and LULUCF categories (i.e. AFOLU) were a net source of 27,707 (±888) kt $CO_2$ eq $yr^{-1}$ between 2016 and 2020.

## 3.3 Observed and Predicted Climate Change: Key Findings

### *3.3.1 Summary of key observed changes to the climate system in Ireland (based on EPA, 2021)*

- In 2019, GHG emissions were the highest since records began and higher than pre-industrial levels, with concentrations of $CO_2$ at 50%, $CH_4$ at 170% and $N_2O$ at 20% higher than pre-industrial levels measured at Mace Head, Galway.
- Mean annual temperature has been increasing at a rate of 0.078°C per decade since 1900 and is now 0.9°C higher than in the early 1900s.
- The period from 2006 to 2015 was the wettest on record, with an observed trend towards an increase in winter rainfall and a decrease in summer rainfall.
- Soil moisture deficits measured at Dublin Airport in June and July 2018 were the highest since records began in 1981.
- The sea level around Ireland has risen by approximately 2–3 mm per year since the early 1990s.

### *3.3.2 Summary of key projected changes in Ireland in the medium term (2041–2060) compared with 1981–2000 (based on Nolan and Flanagan, 2020)*

- The mean annual temperature is projected to increase by 1.0–1.2°C under RCP4.5.
- The maximum temperature is projected to increase by 1.0–2.2°C under RCP4.5.
- Heatwave events are projected to increase by the middle of the century, with the largest increases expected in the south-east of the country.
- The number of frost days is projected to decline by 45% under RCP4.5.
- Annual precipitation is projected to decrease slightly, but there was significant disagreement among the regional climate models included in the ensemble.
- Summer precipitation is projected to decrease by between 0% and 11% under RCP4.5 and by between 2% and 17% under RCP8.5.
- Heavy precipitation events (frequency) are likely to increase by 5–19% by mid-century.
- The growing season is projected to increase by 12%; however, this does not take into consideration the impact of simultaneous increases in climate variability.

## 3.4 Impacts of Climate Change on the Land System: Key Findings

A review of the literature was conducted regarding the expected impacts of climate change on the functioning of the land system. It is expected that $CO_2$ fertilisation and an extended growing season (due to higher spring/summer temperatures) are likely to result in some gains in plant growth across grasslands, croplands and forestry as well as natural systems. However, these will be counteracted by the increase in extreme events such as droughts and heatwaves and other limitations such as nutrient availability. Projected increases in heavy precipitation events are likely to have a severe impact on the trafficability of soil for both livestock and machinery, with consequences for the management of animal grazing, and a range of routine activities for the management of grasslands, croplands and forestry. There are also likely to be impacts on the functioning of peatlands, with the potential for carbon losses where summer droughts result in lower water tables and soil moisture levels. Similarly, higher temperatures increase the risk of wildfires, which could affect habitats and particularly forest and woodland.

## 3.5 Land Use Change Scenarios: Key Findings

In short, only the scenarios that combined high rates of afforestation, substantial peatland rewetting and bold agricultural optimisation measures (ambitious abatement plus herd reduction) were predicted to reach the net-zero target (S4d; Figure 3.3).

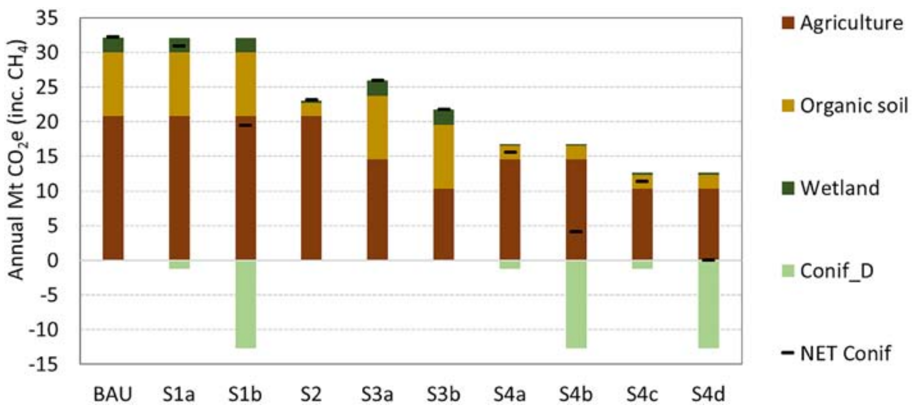


**Figure 3.3. $GWP_{100}$ balance (NET Conif) across emissions sources and forestry sinks for the main scenarios including $CH_4$ emissions. Results are presented for the example of conifer-dominated (Conif_D) forestry (70:30 coniferous to broadleaved species split by land area).**

Individually, all of these measures, even if deployed ambitiously, would fall well short of the target. A summary of key outcomes is provided here but for only the analysis including $CH_4$ in the $GWP_{100}$ balance (in the interest of brevity). See the main report for full details of both analyses.

### *3.5.1 Summary of scenario outcomes with regard to achievement of the target of net-zero emissions from the AFOLU sector in Ireland by 2050*

- Only scenarios that include annual afforestation of 35,000 ha $yr^{-1}$ combined with ambitious organic soil rewetting, ambitious livestock system emissions decoupling and livestock number reductions (i.e. S4d, S5 and S6) were predicted to achieve the net-zero target (Figure 3.3).
- Broadleaf-dominated forests cannot generate sufficiently offset emissions to reach net zero in any of the scenarios (unless the planting area is extended to compensate for the slower rate of biomass production) (Table 3.2).
- However, despite the challenges, it is still possible to reach net zero and leave scope for converting a significant area of land (420,000 ha by 2050) to perennial bioenergy crops (S6) or to space designated for nature (S5). Yet, S7, which involves some conversion of grasslands to croplands, does not achieve net zero (Table 3.2).
- There are a multitude of ways in which 420,000 ha of grasslands could be distributed for alternative usage, depending on local suitability and wider socioeconomic drivers. However, there are limitations to and potential for feedback from land use change and especially soil carbon stocks. For example, because of the impact of tillage, increasing croplands by a modest 10% (S7) would mean that the net-zero target cannot be met (unless animal numbers are reduced by more than 30%).

## 3.6 Impacts of Land Use Change on Ecosystems and the Environment: Key Findings

The AFOLU sector in Ireland has the potential to achieve the net-zero target by 2050 (Table 3.2; S4d), but significant land use change is required (Table 2.1). Depending on the implementation of this land use change, and subsequent land management, AFOLU mitigation measures could have substantial benefits for biodiversity and water. Conversely, poorly targeted land use changes with inappropriate management could result in significant trade-offs for biodiversity and water, while also potentially affecting their effectiveness in climate mitigation (IPCC, 2022). Terrestrial biodiversity loss is intricately linked to how we manage land, while continued biodiversity loss reduces the resilience of ecosystems to climate change extremes (IPBES, 2019). This illustrates the fact that continued biodiversity loss hampers the effectiveness of mitigation within the AFOLU sector and that an evaluation of the trade-offs and synergies of proposed AFOLU land use changes is essential.

Below, the key points regarding each of the main land use changes are outlined; for full details,

**Table 3.2. Scenario emission results including $CH_4$ in GWP balance calculations, with maximum afforestation of 35 kha yr$^{-1}$**

| Scenario | Emissions (kt $CO_2$ eq yr$^{-1}$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Agriculture | Organic soil | Wetlands | SOC | Forestry (Conif_D) | Forestry (Broad_D) | Net balance (Conif_D) | Net balance (Broad_D) |
| BAU | 20,797 | 9168 | 2167 | 0 | 12 | 12 | 32,144 | 32,144 |
| S1a | 20,797 | 9168 | 2132 | 0 | –1260 | –966 | 30,837 | 31,130 |
| S1b | 20,797 | 9168 | 2132 | 0 | –12,707 | –9767 | 19,389 | 22,329 |
| S2 | 20,797 | 1963 | 243 | 0 | 12 | 12 | 23,015 | 23,015 |
| S3a | 14,558 | 9168 | 2132 | 0 | 12 | 12 | 25,869 | 25,869 |
| S3b | 10,398 | 9168 | 2132 | 0 | 12 | 12 | 21,710 | 21,710 |
| S4a | 14,558 | 1963 | 243 | 0 | –1260 | –966 | 15,504 | 15,798 |
| S4b | 14,558 | 1963 | 243 | 0 | –12,707 | –9767 | 4057 | 6997 |
| S4c | 10,398 | 1963 | 243 | 0 | –1260 | –966 | 11,345 | 11,639 |
| S4d | 10,398 | 1963 | 243 | 0 | –12,707 | –9767 | –102 | 2837 |
| S5 | 10,398 | 1963 | 243 | 0 | –12,707 | –9767 | –102 | 2837 |
| S6 | 10,398 | 1963 | 243 | 0 | –12,707 | –9767 | –102 | 2837 |
| S7 | 10,398 | 1963 | 243 | 2266 | –12,707 | –9767 | 2164 | 5103 |

**Net balance results complying with climate neutrality are shaded green. Two scenarios for afforestation are either conifer dominated (Conif_D) or broadleaf dominated (Broad_D), corresponding to a 70:30 or a 30:70 area split, respectively.**
**SOC, soil organic carbon.**

see Chapter 5 in the main report. A high-level and qualitative analysis of the trade-offs and synergies between land use change and other ecosystem services is summarised in Table 3.3.

### *3.6.1 Afforestation*

- When deployed using a sustainable land management approach, afforestation can improve water filtration in soil as well as improving groundwater recharge and reducing soil erosion, run-off and flooding (IPCC, 2019a).
- Afforestation using a mix of native tree species is proven to support ecosystem services, biodiversity and air filtration and have social benefits in terms of, for example, cultural heritage, recreation and health (IPCC, 2019a).
- Nevertheless, the rapid conversion of thousands of hectares of land in Ireland to forestry will potentially have major environmental impacts on biodiversity and water.
- Overall, the scale and direction of impacts of forestry practices on biodiversity and water is context specific and depends on the existing ecological condition of afforested sites, afforestation practices and ongoing forest management.

### *3.6.2 Peatland restoration*

- Peatlands are important areas for biodiversity, and intact peatlands provide multiple ecosystem services in Ireland, including water regulation, erosion and fire prevention, and carbon storage. However, over 80% of Irish peatland ecosystems have been degraded as a result of peat extraction, agriculture and plantation forestry.
- The restoration of peatlands and organic soils has the potential to reduce carbon losses in a relatively short time following rewetting (Renou-Wilson *et al*., 2019). It should be noted that there may be a short-term trade-off with enhanced $CH_4$ emissions due to rewetting, but this would be compensated for by carbon storage through assimilation as the ecological communities develop.
- Rewetting also has potential co-benefits for biodiversity, water quality and water regulation. In some cases, reducing the cost associated with water treatment (for drinking water) and improved flood management both reduces and mitigates peak flows in catchments.

**Table 3.3. Assessment of synergies and trade-offs across the land use change measures included under the set of scenarios considered in this report**

| Land use change | Mitigation | Adaptation | Biodiversity | Water quality | Notes/comments |
|---|---|---|---|---|---|
| **Afforestation** | | | | | |
| | | | | | Forest carbon sinks saturate over time and there is a significant risk of sink reversal due to unsustainable future management or natural disasters (e.g. wildfire). Climate change exacerbates these risks. Afforestation in unsuitable areas (e.g. organic soils) is a concern. The trade-offs and synergies with biodiversity and water depend on the existing ecological condition of the afforested site, species selection and afforestation practices. |
| Conifer dominated | +++ | ± | ± | ± | Afforestation where planting is dominated by non-native conifer species can have a potentially negative impact on biodiversity and water quality, and depends on site-specific characteristics and landscape context. |
| Broadleaf dominated | ++ | ++ | ++ | + | Afforestation with more slower-growing broadleaved species can have a positive impact on biodiversity and water quality. |
| **Agriculture optimisation** | | | | | |
| Increased production efficiency | ++ | ++ | = | ++ | Widely beneficial but could have a net negative impact on mitigation where rebound effects result in increases in absolute emissions. |
| Increased livestock density on grasslands | = | − | − | −− | Likely to have a negative impact on water quality where the density of grassland livestock is increased. Actions can be taken to reduce negative impacts on water quality (such as removing access of livestock to waterways). |
| Decreased livestock density on grasslands | = | ± | ± | + | Likely to have benefits to water quality where density of grassland livestock is reduced; however, this is predicated on appropriate management of livestock (i.e. even at lower density there is potential for adverse outcomes). |
| **Peatland restoration** | | | | | |
| | | | | | Potential future vulnerability with these benefits/synergies under future climates. Drought periods and higher winter temperatures are likely to increase carbon losses from the systems. There is also a greater risk of wildfire during summer drawdown events, which could lead to significant short-term emissions and impact future ability to assimilate carbon and resilience climatic variability. |
| Exploited peatlands | +++ | +++ | +++ | +++ | Expected to be widely beneficial, noting the vulnerability of the carbon sink in future climate. In addition, there are likely to be site-specific constraints on successful implementation. |
| Organic soils under grasslands | +++ | ++ | ++ | ++ | Expected to be widely beneficial, albeit dependent on the level of land use intensity following rewetting. There is considerable uncertainty with regard to the loss of grassland productivity and impact of rewetting on land management (i.e. trafficability for livestock and machinery). |

**Table 3.3. Continued**

| Land use change | Mitigation | Adaptation | Biodiversity | Water quality | Notes/comments |
|---|---|---|---|---|---|
| **Additional land options** | | | | | |
| | | | | | Note that to ensure the availability of land to conduct these measures these scenarios were modelled as additions to scenario S4d. |
| Space for nature (S5) | ++ | ++ | +++ | +++ | Expected to be widely beneficial. There is considerable uncertainty with regard to the loss of grassland productivity. There are likely to be co-benefits for the long-term sustainability of agroecosystem productivity, with positive impacts on nutrient cycling and pollination services. |
| Bioenergy from grasslands (S6) | ++ | ± | ± | ± | Significant potential for mitigation benefits by displacing fossil fuels with bioenergy, which is a renewable source, especially in the case of woody perennial species and perennial grasses. However, this is more variable in the case of anaerobic digestion. |
| Additional croplands (S7) | −− | ++ | ± | ± | Cultivation will result in soil carbon losses from soil currently under grasslands. Impact on biodiversity and water quality could be positive if best practice implementation occurs. Where the additional land is used for annual bioenergy crops, the mitigation potential could improve. Implementing carbon mitigation practices such as minimum tillage could also improve the mitigation potential. |

**The assessment presented in this table is qualitative and based on the expert opinions of the authors.**

## Table indicator notes

| Indicator | Description |
|---|---|
| +++ | Large positive – synergy |
| ++ | Moderate positive – synergy |
| + | Small positive – synergy |
| = | Neutral or low confidence in direction |
| − | Small negative – trade-off |
| −− | Moderate negative |
| −−− | Large negative |
| ± | Variable – may be positive or negative |

#### 3.6.3 Agricultural optimisation

- Increasing the production efficiency of agriculture in Ireland has significant climate mitigation potential through measures ranging from improved genetics for crops, forage plants and livestock, to precision agriculture technologies and integrated soil, water and pest management.
- Under S3, a 30% reduction in agricultural emissions intensity by 2050 is included. This value was taken to represent the upper end of the mitigation potential of agricultural activities based on current technologies.
- Changes in livestock density outlined under S3 are likely to interact strongly with environmental indicators in a site-specific manner. An increase in livestock densities is likely to be associated with a decrease in water quality and biodiversity, particularly in areas with high pollution impact potential.

#### 3.6.4 Options for providing additional space for nature, bioenergy and crops

- Space for nature in the agricultural landscape is also highlighted as having significant co-benefits for climate mitigation, biodiversity and water quality.
- The space for nature scenario (S5) provides for the allocation of 10% of the total grassland area in 2018 to biodiversity and associated ecosystem services. In practice, it is likely that the 10% target in S5 has already been met on many grassland farms in Ireland. However, because of the limited resolution of available land cover data it was not possible to account for this.
- The picture for bioenergy from grasslands and additional cropland is mixed, with the potential for significant trade-offs with biodiversity and water depending on the intensity of the land use being replaced.
- There is potential for significant benefits in terms of national-level food and feed security where more land is used for crop and horticulture production. However, the cultivation of land currently in the grassland category will result in soil carbon losses due to tillage. The implementation of minimum tillage practices could reduce negative impacts on carbon stocks.

### 3.7 Land Use Change and Policy Interactions: Key Findings

The scenarios outlined in Chapter 4 of the main report include large changes in land use at the national level targeted at achieving net-zero emissions from AFOLU by 2050. Many of the land use changes required for net-zero AFOLU emissions identified in Chapter 4 are not in line with current land use policy targets.

- Afforestation – current policy targets are relatively consistent, at 8000 ha $yr^{-1}$, across multiple policy documents. This level of afforestation falls short of the rates compatible with meeting net-zero targets by mid-century (based on the indicative scenarios developed in this report), which are between 20,000 and 35,000 ha $yr^{-1}$, depending on whether $CH_4$ is included in the targets.
- Wetlands – the peatland restoration targets outlined in policy documents were less coherent than the afforestation targets. Policy targets for the restoration of peatlands ranged from 33,000 ha for exploited peatlands to 80,000 ha for drained organic soils under grasslands. These fall short of the 70,000 ha for exploited peatlands and 302,000 ha for drained organic soils under grasslands as identified under S2.
- Agriculture optimisation – improving the efficiency of agricultural production and so lowering the emissions intensity associated per unit of food output is a central target of many actions in the Ag Climatise Plan (DAFM, 2020). This policy analysis did not find any specific targets in relation to reductions in ruminant livestock numbers.
- Biodiversity – of all the actions included in the set of scenarios developed in this report, the target of allocating 10% of space for nature most closely agrees with key national and EU policies. For example, Food Vision 2030 specifies a target of 10% of farmed land being "prioritised for biodiversity", and Ag Climatise mentions increasing biodiversity as a key objective across several actions (DAFM, 2020, 2021).
- Bioenergy and additional croplands – in general, policy targets do not align with the type of non-forestry bioenergy that is included in S6.

# 4 Conclusions and Policy Recommendations

Scenario modelling makes it clear that achieving the AFOLU net-zero target will require the substantial reconfiguration of land use across Ireland in the coming decades. The success of this reconfiguration will need to be measured in terms of contribution to climate mitigation and adaption, just transition across society, and minimising trade-offs and maximising synergies with other ecosystem services, while ensuring that reconfiguration does not exacerbate other global society challenges (e.g. biodiversity loss, food and water security). This will require an integrated land use strategy coordinated by a whole-government approach, while ensuring buy-in from and participation by the whole of society.

Many of the land use change that are compatible with net-zero targets for AFOLU provide considerable co-benefits across environmental indicators and so represent areas where actions could take place in the near term. However, for other actions significant trade-offs exist, and careful planning and implementation is required to minimise negative impacts. Land management options targeted at climate mitigation, including afforestation and bioenergy crops, can pose unintentional threats to biodiversity and water quality, particularly where they are deployed as monocultures covering large areas (IPCC, 2019b). Where agriculture and forest areas coincide with existing important areas for biodiversity, there may be significant barriers to and trade-offs associated with land use change, exacerbated by conflicting land use objectives associated with different energy, food, biodiversity, water and climate policies.

The Irish landscape encompasses a wide range of land types characterised by differences in geology, topography, soils, climate and land cover (Carlier *et al*., 2021). This landscape variation requires regional and local adaptation of national policy targets, similar to the integrated catchment management approach to the implementation of the Water Framework Directive and the locally adapted agri-environmental scheme approach as exemplified by the Burren programme (Murray, 2020). Local participatory approaches are recognised as essential components of integrated catchment management approaches and locally adapted agri-environment schemes in Ireland.

## 4.1 Integrated Land Use Planning

Given the broad range of land use objectives, it is essential that an overall integrated approach to land management and land use planning is developed. An integrated approach aims to target land use to meet multiple goals while being cognisant of the trade-offs and synergies between them, and balancing environmental, social and economic outcomes. This requires strategic targeting of land use that acknowledges the varying capacity of different land types to provide a diverse range of ecosystem services, from provisioning (e.g. food and fibre), regulating (e.g. climate, water) and supporting (e.g. nutrient cycling) services to cultural (aesthetic, recreation) services. The approach would support policymakers, land managers and land users in selecting the appropriate land use strategies to meet the needs of society while protecting natural resources and ensuring the continued supply of ecosystem services from functioning ecosystems in good condition. In an unmanaged land use change transition, the individual choices for intensification, expansion and drainage are neither based on nor optimised for knowledge about soil type, soil properties, soil nutrient levels or soil carbon contents. In contrast to the unmanaged scenario, a managed land use transition would ensure that pathways are customised for the properties of individual fields, soils or catchments (Valujeva *et al*., 2016).

## 4.2 Climate Mitigation Targets for AFOLU and Wider Policy Objectives

As explored in detail in Chapter 2 of the main report, agricultural activities and related land use are overall a significant source of GHG emissions in Ireland. It should be noted that much of the mitigation potential lies in land use and not only in changes to direct agricultural activities. Identifying mitigation measures along with a sector-specific emissions budget is a logical economic response to climate change. Possible measures include the following:

- Better integration of livestock farming with crop systems could lead to more diversified farm enterprises and improve sustainability and circularity with regard to nutrient cycling on individual farms (Khalil and Osborne, 2022).
- Agricultural system diversification can also support increased farm resilience to both climate and economic shocks. Examples of such agricultural system redesign include the implementation of alternative farming systems such as organic farming, agroforestry or intercropping (Haughey *et al*., 2019).
- However, there are significant barriers, including the need for investment in new farming systems, a lack of enabling conditions in terms of access to or development of new markets, and restrictive agricultural policies (Hurlbert *et al*., 2019).
- Additional research addressing barriers to uptake of alternatives is needed, as is additional engagement with stakeholders regarding the wider benefits of diversification such as increasing resilience to extreme climate events.

## 4.3 Knowledge Gaps and Key Uncertainties

There are important knowledge gaps that hamper rapid progress in terms of effective land use change. These include a lack of a high-resolution land use map for Ireland; however, work is under way to address this. Other important considerations include the need for effective knowledge sharing with land managers to enable effective and timely climate actions; the relatively high level of uncertainty regarding the impact of climate variability and extremes on the functioning of the land system; further climate impacts on water quality; interactions between climate change and trends in infrastructure development; and uncertainty regarding the potential contribution of areas of semi-natural vegetation to climate mitigation.

Areas where key data or knowledge gaps exist include:

- spatial land use and land cover data (main report section 6.3.1);
- knowledge sharing for co-creation of solutions (main report section 6.3.2);
- impact of climate variability and extreme events on ecosystem functioning (main report section 6.3.3);
- water quality and quantity under future climate (main report section 6.3.4);
- infrastructure and urbanisation (main report section 6.3.5);
- climate services provided by semi-natural land (main report section 6.3.6);
- terrestrial carbon and GHG flux observation systems (main report section 6.3.7).

# References


Arneth, A., Denton, F., Agus, F., Elbehri, A., Erb, K., Osman Elasha, B., Rahimi, M., Rounsevell, M., Spence, A. and Valentini, R., 2019. Framing and context. In Shukla, P.R., Skea, J., Calvo Buendia, E., Masson-Delmotte, V., Pörtner, H.-O., Roberts, D.C., Zhai, P., Slade, R., Connors, S., van Diemen, R., Ferrat, M., Haughey, E., Luz, S., Neogi, S., Pathak, M., Petzold, J., Portugal Pereira, J., Vyas, P., Huntley, E., Kissick, K., Belkacemi, M. and Malley, J. (eds), *Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*. Cambridge University Press, UK, and New York, NY.

Carlier, J., Doyle, M., Finn, J., Ó hUallacháin, D. and Moran, J., 2021. A landscape classification map of Ireland and its potential use in national land use monitoring. *Journal of Environmental Management* 289: 112498.

CORINE, 2018. CORINE Land Cover (CLC) 2018, Version 2020_20u1. Available online: https://land.copernicus.eu/pan-european/corine-land-cover/clc2018?tab=metadata (accessed 18 January 2023).

CSO (Central Statistics Office), 2020. Census of Agriculture 2020 – preliminary results. Table 2.3: Number of farms by region, county and farm type, 2020. Available online: https://www.cso.ie/en/releasesandpublications/ep/p-coa/censusofagriculture2020-preliminaryresults/farmstructure/ (accessed 30 August 2022).

CSO (Central Statistics Office), 2021. Environmental Indicators Ireland 2021: land use categories 1990–2019. Available online: https://www.cso.ie/en/releasesandpublications/ep/p-eii/environmentalindicatorsireland2021/landuse/ (accessed 27 April 2022).

DAFM (Department of Agriculture, Food and the Marine), 2020. *Ag Climatise: A Roadmap to Climate Neturality*. Dublin. Available online: https://www.gov.ie/en/publication/07fbe-ag-climatise-a-roadmap-towards-climate-neutrality/ (accessed 18 January 2023).

DAFM (Department of Agriculture, Food and the Marine), 2021a. *Annual Report 2020*. Department of Agriculture, Food and the Marine, Dublin.

DAFM (Department of Agriculture, Food and the Marine), 2021b. *Food Vision 2030: A World Leader in Sustainable Food Systems*. Dublin. Available online: https://www.gov.ie/en/publication/c73a3-food-vision-2030-a-world-leader-in-sustainable-food-systems/ (accessed 18 January 2023).

DAFM (Department of Agriculture, Food and the Marine), 2022. *Forest Statistics Ireland 2022*. Johnstown Castle, Ireland. Available online: https://www.gov.ie/en/collection/15b56-forest-statistics-and-mapping/#annual-forest-sector-statistics (accessed 18 January 2023).

EEA (European Environment Agency), 2021. EEA greenhouse gases – data viewer. Available online: https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer (accessed 23 August 2022).

EPA (Environmental Protection Agency), 2021. *Climate Status Report for Ireland 2020*. Johnstown Castle, Ireland. Available online: https://www.epa.ie/publications/research/climate-change/research-386-the-status-of-irelands-climate-2020.php (accessed 18 January 2023).

EPA (Environmental Protection Agency), 2022a. *Ireland's National Inventory Report 2022: Greenhouse Gas Emissions 1990–2020 Reported to the United Nations Framework Convention on Climate Change*. Johnstown Castle, Ireland. Available online: https://www.epa.ie/publications/monitoring--assessment/climate-change/air-emissions/irelands-national-inventory-submissions-2022.php (accessed 18 January 2023).

EPA (Environmental Protection Agency), 2022b. Latest emissions data. Available online: https://www.epa.ie/our-services/monitoring--assessment/climate-change/ghg/latest-emissions-data/ (accessed 18 January 2023).

Haughey, E., 2021. *Climate Change and Land Use in Ireland*. Environmental Protection Agency, Johnstown Castle, Ireland.

Haughey, E., Benton, T., Cowie, A., Olsson, L. and Smith, P., 2019. Cross-chapter box 6: agricultural intensification: land sparing, land sharing and sustainability. In Shukla, P.R., Skea, J., Calvo Buendia, E., Masson-Delmotte, V., Pörtner, H.-O., Roberts, D.C., Zhai, P., Slade, R., Connors, S., van Diemen, R., Ferrat, M., Haughey, E., Luz, S., Neogi, S., Pathak, M., Petzold, J., Portugal Pereira, J., Vyas, P., Huntley, E., Kissick, K., Belkacemi, M. and Malley, J. (eds), *Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*. Cambridge University Press, UK, and New York, NY, pp. 502–505.

Hurlbert, M., Krishnaswamy, J., Davin, E., Johnson, F.X., Mena, C.F., Morton, J., Myeong, S., Viner, D., Warner, K., Wreford, A., Zakieldeen, S. and Zommers, Z., 2019. Risk management and decision making in relation to sustainable development. In Shukla, P.R., Skea, J., Calvo Buendia, E., Masson-Delmotte, V., Pörtner, H.-O., Roberts, D.C., Zhai, P., Slade, R., Connors, S., van Diemen, R., Ferrat, M., Haughey, E., Luz, S., Neogi, S., Pathak, M., Petzold, J., Portugal Pereira, J., Vyas, P., Huntley, E., Kissick, K., Belkacemi, M. and Malley, J. (eds), *Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*. Cambridge University Press, UK, and New York, NY, pp. 673–800.

IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services), 2019. Summary for policymakers. In Díaz, S., Settele, J., Brondízio, E.S., Ngo, H.T., Guèze, M., Agard, J., Arneth, A., Balvanera, P., Brauman, K.A., Butchart, S.H.M., Chan, K.M.A., Garibaldi, L.A., Ichii, K., Liu, J., Subramanian, S.M., Midgley, G.F., Miloslavich, P., Molnár, Z., Obura, D., Pfaff, A., Polasky, S., Purvis, A., Razzaque, J., Reyers, B., Chowdhury, R., Shin, Y.J., Visseren-Hamakers, I.J., Willis, K.J. and Zayas, C.N. (eds), *Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany.

IPCC (Intergovernmental Panel on Climate Change), 2019a. *Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*. Cambridge University Press, UK, and New York, NY.

IPCC (Intergovernmental Panel on Climate Change), 2019b. Summary for policymakers. In Shukla, P.R., Skea, J., Calvo Buendia, E., Masson-Delmotte, V., Pörtner, H.-O., Roberts, D.C., Zhai, P., Slade, R., Connors, S., van Diemen, R., Ferrat, M., Haughey, E., Luz, S., Neogi, S., Pathak, M., Petzold, J., Portugal Pereira, J., Vyas, P., Huntley, E., Kissick, K., Belkacemi, M. and Malley J. (eds), *Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*. Cambridge University Press, UK, and New York, NY, p. 41.

IPCC (Intergovernmental Panel on Climate Change), 2021. *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S.L., Péan, C., Berger, S., Caud, N., Chen, Y., Goldfarb, L., Gomis, M.I., Huang, M., Leitzell, K., Lonnoy, E., Matthews, J.B.R., Maycock, T.K., Waterfield, T., Yelekçi, O., Yu, R. and Zhou, B. (eds)). Cambridge University Press, Cambridge, UK, and New York, NY.

IPCC (Intergovernmental Panel on Climate Change), 2022. *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (Shukla, P.R., Skea, J., Slade, R., Al Khourdajie, A., van Diemen, R., McCollum, D., Pathak, M., Some, S., Vyas, P., Fradera, R., Belkacemi, M., Hasija, A., Lisboa, G., Luz, S. and Malley, J. (eds)). Cambridge University Press, Cambridge, UK, and New York, NY.

Khalil, M.I. and Osborne B., 2022. Developing climate-resilient agri-environmental production systems. *Nutrient Cycling in Agroecosystems* 123: 1–4.

Murray, C., 2020. *Evaluation of the Burren Programme.* Prepared for the Department of Agriculture, Food and the Marine by AECOM Ireland Limited. Available online: https://assets.gov.ie/98196/f13c1130-66d6-4da2-af34-378c92ccb571.pdf (accessed 18 January 2023).

Nolan, P. and Flanagan, J., 2020. *High-resolution Climate Projections for Ireland – A Multimodel Ensemble Approach.* Environmental Protection Agency, Johnstown Castle, Ireland. Available online: https://www.epa.ie/publications/research/climate-change/research-339-high-resolution-climate-projections-for-ireland-.php (accessed 18 January 2023).

QGIS, 2022. QGIS: a free and open source geographic information system. Open Source Geospatial Foundation Project. Available online: http://qgis.osgeo.org (accessed 18 January 2023).

Renou-Wilson, F., 2018. Peatlands. In Creamer, R. and O'Sullivan, L. (eds), *The Soils of Ireland*. Springer International Publishing, Switzerland.

Renou-Wilson, F., Moser, G., Fallon, D., Farrell, C.A., Müller, C. and Wilson, D., 2019. Rewetting degraded peatlands for climate and biodiversity benefits: results from two raised bogs. *Ecological Engineering* 127: 547–560. https://doi.org/10.1016/j.ecoleng.2018.02.014

Valujeva, K., O'Sullivan, L., Gutzler, C., Fealy, R. and Schulte, R.P., 2016. The challenge of managing soil functions at multiple scales: an optimisation study of the synergistic and antagonistic trade-offs between soil functions in Ireland. *Land Use Policy* 58: 335–347.

# Abbreviations

| | |
|---|---|
| **AFOLU** | Agriculture, forestry and other land use |
| **$CO_2$ eq** | Carbon dioxide equivalent |
| **CSO** | Central Statistics Office |
| **EU** | European Union |
| **GHG** | Greenhouse gas |
| **GWP** | Global warming potential |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **LULUCF** | Land use, land use change and forestry |
| **NUTS** | Nomenclature of Territorial Units for Statistics |
| **RCP** | Representative concentration pathway |

# An Ghníomhaireacht Um Chaomhnú Comhshaoil

Tá an GCC freagrach as an gcomhshaol a chosaint agus a fheabhsú, mar shócmhainn luachmhar do mhuintir na hÉireann. Táimid tiomanta do dhaoine agus don chomhshaol a chosaint ar thionchar díobhálach na radaíochta agus an truaillithe.

## Is féidir obair na Gníomhaireachta a roinnt ina trí phríomhréimse:

**Rialáil:** Rialáil agus córais chomhlíonta comhshaoil éifeachtacha a chur i bhfeidhm, chun dea-thorthaí comhshaoil a bhaint amach agus díriú orthu siúd nach mbíonn ag cloí leo.

**Eolas:** Sonraí, eolas agus measúnú ardchaighdeáin, spriocdhírithe agus tráthúil a chur ar fáil i leith an chomhshaoil chun bonn eolais a chur faoin gcinnteoireacht.

**Abhcóideacht:** Ag obair le daoine eile ar son timpeallachta glaine, táirgiúla agus dea-chosanta agus ar son cleachtas inbhuanaithe i dtaobh an chomhshaoil.

## I measc ár gcuid freagrachtaí tá:

### Ceadúnú

- Gníomhaíochtaí tionscail, dramhaíola agus stórála peitril ar scála mór;
- Sceitheadh fuíolluisce uirbigh;
- Úsáid shrianta agus scaoileadh rialaithe Orgánach Géinmhodhnaithe;
- Foinsí radaíochta ianúcháin;
- Astaíochtaí gás ceaptha teasa ó thionscal agus ón eitlíocht trí Scéim an AE um Thrádáil Astaíochtaí.

### Forfheidhmiú Náisiúnta i leith Cúrsaí Comhshaoil

- Iniúchadh agus cigireacht ar shaoráidí a bhfuil ceadúnas acu ón GCC;
- Cur i bhfeidhm an dea-chleachtais a stiúradh i ngníomhaíochtaí agus i saoráidí rialáilte;
- Maoirseacht a dhéanamh ar fhreagrachtaí an údaráis áitiúil as cosaint an chomhshaoil;
- Caighdeán an uisce óil phoiblí a rialáil agus údaruithe um sceitheadh fuíolluisce uirbigh a fhorfheidhmiú
- Caighdeán an uisce óil phoiblí agus phríobháidigh a mheasúnú agus tuairisciú air;
- Comhordú a dhéanamh ar líonra d'eagraíochtaí seirbhíse poiblí chun tacú le gníomhú i gcoinne coireachta comhshaoil;
- An dlí a chur orthu siúd a bhriseann dlí an chomhshaoil agus a dhéanann dochar don chomhshaol.

### Bainistíocht Dramhaíola agus Ceimiceáin sa Chomhshaol

- Rialacháin dramhaíola a chur i bhfeidhm agus a fhorfheidhmiú lena n-áirítear saincheisteanna forfheidhmithe náisiúnta;
- Staitisticí dramhaíola náisiúnta a ullmhú agus a fhoilsiú chomh maith leis an bPlean Náisiúnta um Bainistíocht Dramhaíola Guaisí;
- An Clár Náisiúnta um Chosc Dramhaíola a fhorbairt agus a chur i bhfeidhm;
- Reachtaíocht ar rialú ceimiceán sa timpeallacht a chur i bhfeidhm agus tuairisciú ar an reachtaíocht sin.

### Bainistíocht Uisce

- Plé le struchtúir náisiúnta agus réigiúnacha rialachais agus oibriúcháin chun an Chreat-treoir Uisce a chur i bhfeidhm;
- Monatóireacht, measúnú agus tuairisciú a dhéanamh ar chaighdeán aibhneacha, lochanna, uiscí idirchreasa agus cósta, uiscí snámha agus screamhuisce chomh maith le tomhas ar leibhéil uisce agus sreabhadh abhann.

### Eolaíocht Aeráide & Athrú Aeráide

- Fardail agus réamh-mheastacháin a fhoilsiú um astaíochtaí gás ceaptha teasa na hÉireann;
- Rúnaíocht a chur ar fáil don Chomhairle Chomhairleach ar Athrú Aeráide agus tacaíocht a thabhairt don Idirphlé Náisiúnta ar Ghníomhú ar son na hAeráide;
- Tacú le gníomhaíochtaí forbartha Náisiúnta, AE agus NA um Eolaíocht agus Beartas Aeráide.

### Monatóireacht & Measúnú ar an gComhshaol

- Córais náisiúnta um monatóireacht an chomhshaoil a cheapadh agus a chur i bhfeidhm: teicneolaíocht, bainistíocht sonraí, anailís agus réamhaisnéisiú;
- Tuairiscí ar Staid Thimpeallacht na hÉireann agus ar Tháscairí a chur ar fáil;
- Monatóireacht a dhéanamh ar chaighdeán an aeir agus Treoir an AE i leith Aeir Ghlain don Eoraip a chur i bhfeidhm chomh maith leis an gCoinbhinsiún ar Aerthruailliú Fadraoin Trasteorann, agus an Treoir i leith na Teorann Náisiúnta Astaíochtaí;
- Maoirseacht a dhéanamh ar chur i bhfeidhm na Treorach i leith Torainn Timpeallachta;
- Measúnú a dhéanamh ar thionchar pleananna agus clár beartaithe ar chomhshaol na hÉireann.

### Taighde agus Forbairt Comhshaoil

- Comhordú a dhéanamh ar ghníomhaíochtaí taighde comhshaoil agus iad a mhaoiniú chun brú a aithint, bonn eolais a chur faoin mbeartas agus réitigh a chur ar fáil;
- Comhoibriú le gníomhaíocht náisiúnta agus AE um thaighde comhshaoil.

### Cosaint Raideolaíoch

- Monatóireacht a dhéanamh ar leibhéil radaíochta agus nochtadh an phobail do radaíocht ianúcháin agus do réimsí leictreamaighnéadacha a mheas;
- Cabhrú le pleananna náisiúnta a fhorbairt le haghaidh éigeandálaí ag eascairt as taismí núicléacha;
- Monatóireacht a dhéanamh ar fhorbairtí thar lear a bhaineann le saoráidí núicléacha agus leis an tsábháilteacht raideolaíochta;
- Sainseirbhísí um chosaint ar an radaíocht a sholáthar, nó maoirsiú a dhéanamh ar sholáthar na seirbhísí sin.

### Treoir, Ardú Feasachta agus Faisnéis Inrochtana

- Tuairisciú, comhairle agus treoir neamhspleách, fianaise-bhunaithe a chur ar fáil don Rialtas, don tionscal agus don phobal ar ábhair maidir le cosaint comhshaoil agus raideolaíoch;
- An nasc idir sláinte agus folláine, an geilleagar agus timpeallacht ghlan a chur chun cinn;
- Feasacht comhshaoil a chur chun cinn lena n-áirítear tacú le hiompraíocht um éifeachtúlacht acmhainní agus aistriú aeráide;
- Tástáil radóin a chur chun cinn i dtithe agus in ionaid oibre agus feabhsúchán a mholadh áit is gá.

### Comhpháirtíocht agus Líonrú

- Oibriú le gníomhaireachtaí idirnáisiúnta agus náisiúnta, údaráis réigiúnacha agus áitiúla, eagraíochtaí neamhrialtais, comhlachtaí ionadaíocha agus ranna rialtais chun cosaint chomhshaoil agus raideolaíoch a chur ar fáil, chomh maith le taighde, comhordú agus cinnteoireacht bunaithe ar an eolaíocht.

## Bainistíocht agus struchtúr na Gníomhaireachta um Chaomhnú Comhshaoil

Tá an GCC á bainistiú ag Bord lánaimseartha, ar a bhfuil Ard-Stiúrthóir agus cúigear Stiúrthóir. Déantar an obair ar fud cúig cinn d'Oifigí:

1. An Oifig um Inbhunaitheacht i leith Cúrsaí Comhshaoil
2. An Oifig Forfheidhmithe i leith Cúrsaí Comhshaoil
3. An Oifig um Fhianaise agus Measúnú
4. An Oifig um Chosaint ar Radaíocht agus Monatóireacht Comhshaoil
5. An Oifig Cumarsáide agus Seirbhísí Corparáideacha

Tugann coistí comhairleacha cabhair don Ghníomhaireacht agus tagann siad le chéile go rialta le plé a dhéanamh ar ábhair imní agus le comhairle a chur ar an mBord.

# Evidence Synthesis Report: 4

# Land Use Review: Fluxes, Scenarios and Capacity Synthesis Report

**Authors:**

Eamon Haughey, David Styles, Matthew Saunders, Ruth Bennett Coady and James Moran

**EPA Research:** McCumiskey House, Richiew, Clonskeagh, Dublin 14.

**Phone:** 01 268 0100
**Twitter:** @EPAResearchNews
**Email:** research@epa.ie

**EPA Research Webpages**
www.epa.ie/our-services/research/

**www.epa.ie**

Rialtas na hÉireann
Government of Ireland